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Proceedings of conference of collaborators from Southern Agricultural Experiment Stations Agricultural research and pollution

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PREFACE

This Conference was sponsored jointly by the Southern Agricultural Experiment Stations and Southern Marketing and Nutrition Research Division of Agricultural Research Service, U.S. Department of Agriculture. Its purpose was to exchange information that directly benefits the Stations, the Divisions of the Agricultural Research Service, and others.

The theme for the 1970 meeting was "Agricultural Research and Pollution". There were three sessions — the first dealing with various topics related to the general theme, the second with pollution abatement research specific to the States in the Southern Region, and the third with the diminution of pollution in processing.

These proceedings report in full the statements presented by the various speakers during the conference and give an account of the discussions following.

C. H. FISHER, Director
Southern Marketing and Nutrition
Research Division

DEDICATION

This Conference is dedicated to Dr. Louis E. Hawkins in recognition of his tireless devotion to serving mankind by the achievement of better living through agricultural research.

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Underscored numbers in parentheses refer to references at the end of each paper. References, figures, and tables are reproduced essentially as they were supplied by the author of each paper.

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OPENING REMARKS

by
C. H. Fisher
Southern Marketing and Nutrition Research Division
New Orleans, La.

It is again my great privilege — representing the Southern Marketing and Nutrition Research Division — to welcome those attending the Conference of Collaborators from the Southern Agricultural Experiment Stations. I welcome you also on behalf of our Agricultural Research Service officials in Washington, namely: Administrator, G. W. Irving, Jr.; Associate Administrator, T. W. Edminster; and Deputy Administrator, F. R. Senti.

It is an extra treat when Deans of Agriculture and other Administrators from the States and USDA attend our conferences. For this reason, I give a special welcome to: L. E. Hawkins, Director-at-Large for the Southern Region; Doyle Chambers, H. Rouse Caffey, J. A. Hendrix and Dave Pearce of Louisiana; P. H. Massey from Virginia; R. D. Rouse from Alabama, Wm. P. Flatt and E. B. Browne from Georgia; John S. Robins from Washington; Walter K. Porter, Jr., from Mississippi; and C. H. Harry Neufeld from Athens, Ga.

The name of Dean E. V. Smith of Alabama was on the list, but I learned only recently that he cannot be here because of serious illness in his family. I know that you are disappointed and sympathetic — as I am.

The present conference — and the Collaborators' Conferences that have gone before — are good evidence that we are working cooperatively with our friends in the States to reach our important goals. We always have been — and we continue to be — exceedingly grateful because we have the privilege of working cooperatively with representatives of the States and other organizations.

Regretfully, those who attended the earliest Collaborators' Conferences, about 30 years ago, are no longer participants. We are pleased, however, because one of the "old timers" is attending this conference as a special guest of honor. I am told that Louis Hawkins attended one of our Collaborators' Conferences as early as 1943.

Pollution problems cause many to claim that we are entering a crucial decade for humanity. One particularly pessimistic book on this subject, entitled "This Little Planet" proposes that mankind may be doomed to extinction because of his wasteful sins with the ecology. The book claims that we spent $2 thousand on war for every $1 spent to fend off the advancing avalanche of pollution that will soon crush us. According to the authors, man is nature's greatest mistake.

One good presentation on the optimistic side is entitled "Good Things About the U.S. Today." I recommend this 256-page book for anyone who needs encouragement and would like to have a summary of the good things about our present existence. Encouraging also is a recent article by Philip Handler, President of the National Academy of Sciences. This article has the cheerful title: "Science Can Make Our Dreams Come True" (Nutrition Today, Jan-Feb 1971, pp. 10-13, 23-27).

The number of people has a great impact on the quality of our environment. It has been pointed out that every 8.5 seconds a new American is born and begins to scream loudly in a voice that can be heard for 70 years. He is screaming for 56 million gallons of water, 21,000 gallons of gasoline, 10,150 pounds of meat, 28,000 pounds of milk and cream, 9,000 pounds of wheat, and great storehouses of other foods and drinks. These are his lifetime demands on his country and its economy. (Readers' Digest, 1971. p. 20, Jan.

The people problem, severe in the United States, seems to be even more severe for the world as a whole. It has been estimated that the human population of 6,000 B.C. was about 5 million people, compared with an anticipated 7 billion people in the year 2000. A child born today, living on to his seventies, would know a world of 15 billion. His grandson would share the planet with 60 billion, or 17 times more people than today. (La. Cooperative Extension Service, Jan. 20, 1971).

But there may be some gold in the garbage. Meaning that pollution wastes — through recycling — may become a valuable raw material. In the past, we have considered farm crops, timber, petroleum, natural gas, and minerals as our principal raw materials. Probably pollution wastes will become a major raw material. Each day the average American tosses out more than 5-1/3 pounds of solid waste. Hence, the quantity is adequate for raw material purposes (Newsweek, February 1, 1971, "Gold in Garbage").

It is well known that agricultural research has been productive, in general, in solving agricultural and agribusiness problems. It is less well known, however, that agricultural research has been alert and productive also in protecting our environment. In fact, nearly 20 years ago, we had already done considerable research on utilization of byproducts of Southern agriculture.[1]

During the same 30 years of the Southern Regional Research Laboratory and the Collaborators' Conference, agricultural research by the States and USDA has achieved a great deal in the area of environmental quality. That this is so was pointed out at our Collaborators' Conference in 1970. A more complete review of Southern Division research that has benefited the environment was presented by our Mack Stansbury at the 1970 Conference of Collaborators of the Eastern Division in Philadelphia. Repeating, it just happens to be a fact that much of what we call agricultural research does naturally contribute to the quality of our environment. In general, food processing and dehydration studies benefit the environment. The processed product contains no byproduct, other than packaging materials, to contaminate the environment when it is received by the consumer.

The advantages of food dehydration research may be illustrated by one specific product, namely, frozen citrus concentrates, which is purchased by the consumer today at the rate of more than $1 million per day. Before frozen orange concentrate was developed, fresh fruit was shipped all over the country, consuming additional fuel and thus contributing to air pollution. About half of the fruit was eaten; the other half was discarded as garbage. In fact, if the fresh oranges had been used last year instead of frozen concentrates, from Florida alone; approximately 4 billion additional pounds of garbage would have resulted. But now 78 percent of the Florida orange crop is used as concentrates. And these are its contributions to environmental quality:

First, the fuel requirement for shipping is reduced by about 85 percent, thereby conserving an important nonrenewable resource and reducing air pollution.

Second, the amount of packaging materials to be discarded is decreased.

Third, instead of generating large quantities of garbage throughout the country, the byproducts of wastes are dehydrated at the processing plants and used as feed. Thus, the development of citrus concentrates, cooperatively by Florida State and USDA scientists, has made a tremendous contribution to environmental quality and conservation of nonrenewable natural resources.

Food dehydration research has benefited also our space and lunar landing programs. More specifically, orange juice solids prepared at our Winter Haven Laboratory went on Apollo flights 13 and 14. It is not every processed food product that can make the claim that it has been consumed on the moon.

The conference beginning today is not the only one sponsored by the Southern Division to exchange information about pollution problems and their abatement. An earlier conference on pollution abatement — jointly sponsored with the Louisiana sweetpotato industry — was held in New Orleans on August 26, 1969. Proceedings of that conference on "The Treatment and Disposal of Wastes from Vegetable Processing: Progress and Research Needs" are available.

Returning to today's conference, our Program Committee, chaired by H. Rouse Caffey and Bruno H. Wojcik, has arranged a splendid program featuring excellent and distinguished speakers and chairmen.

I wish to thank the Program Committee and all others contributing to the Conference, including the Directors of the Southern Agricultural Stations, for wise counsel and cooperation in sponsoring and planning our conference; General Chairman P. H. Massey, Jr., L. E. Hawkins, E. V. Smith, and J. S. Robins for special presentations; our Session Chairmen and speakers; our Conference Coordinator, Mrs. Shirley Saucier; and Ralph M. Persell, Vernon R. Bourdette, and Marie Jones for their valuable assistance.

I hope that this conference will be highly successful and helpful for all of us. I cordially invite all of you to visit our Laboratory on the Lakefront today, or whenever you are in New Orleans.

---

[1] C. H. Fisher. Utilization of by-products of Southern Agriculture. Jour. South. Res. 4(2): 16-19. 1952.

RESPONSE

by
P. Howard Massey, Jr.
General Chairman

It is a genuine pleasure to participate in the 1971 Collaborators Conference. The theme for the Conference this year is appropriately entitled AGRICULTURAL RESEARCH AND POLLUTION. A more pertinent or relevant topic could not have been selected. The agencies involved in the Conference — Southern Land-Grant Universities, Cooperative State Research Service, and the United States Department of Agriculture — have traditionally concerned themselves with problems of people. Our expertise in rural areas as well as for research and education qualifies us to handle the difficult assignments faced today — for example, controlling pests and protecting men and environment. The successful programs we have developed and conducted — for example, reforestation, soil and water conservation, and improving agricultural practices — indicate that we can get tough jobs done efficiently.

Some positive actions that can be cited to indicate the effective working relationships between the State and Federal agencies are:

(1) The development of the long-range program for agriculture.

(2) Task forces
  A. National
  B. Regional — Example in Southern Region:
    Environmental quality.

(3) Initiation of regular joint program planning.

Therefore, it can be noted that we are working together to accomplish agriculture's missions:

(1) To provide life's essentials — food, fiber, water, living space, and human satisfaction and...

(2) To protect and improve the physical environment — soil and water conservation, control of pests, and food safety.

Today, we will focus attention on our efforts to overcome and prevent degradation of the environment — pollution. The Conference Program Committee has assembled a distinguished group of speakers and specified relevant topics, and thereby has assured an outstanding program.

AGRICULTURE'S ROLE AND RESPONSIBILITY IN THE CONTROL OF POLLUTION

by
J. S. Robins
Cooperative State Research Service
Washington, D.C.

Mr. Chairman and fellow agriculturalists. It is a real pleasure to be here in New Orleans and to serve as keynoter for your 1971 Collaborators' Conference.

Before getting to the assigned topic, I would like to digress to comment on the dedication of this conference. The words on the inside cover of your program "in recognition of his tireless devotion to serving mankind by the achievement of better living through agricultural research" are highly appropriate and perfectly applied to our mutual friend, Louis Hawkins. My personal congratulations and good wishes to you, Louis, on this highly deserved recognition.

I also commend you in the Southern Experiment Stations and you and your staff of the SMNRD, Dr. Fisher, on selection of a most pertinent theme for this conference. Aside from war and crime, and in the minds of some, possibly drugs and world population, I suspect that environmental quality has few peers in terms of a national concensus of concern in this country, and around the world for that matter. And pollution of our natural environment is certainly a major part of the total environmental quality issue.

Some use the terms "pollution" and "environmental quality" interchangeably. To me, pollution is more nearly synonymous with degradation of the quality of the natural environment — degradation that reduces its utility by man. Such degradation generally causes an adverse physical or biologic response and necessitates a cost input to make the degraded element useful.

For example, chemicals, sediment, organic material, heat, or cans and bottles in a water body or stream may degrade the water for man's use and require cost inputs to return the water to a useful state. Dust or other particulates, carbon monoxide, organic vapors, ozone or noise may reduce the utility of our atmosphere. Toxins, microbes, certain organic or inorganic chemicals may degrade food quality. Soils may be polluted with salts, with pesticides or toxic metals, with radionucleotides, or with organic wastes.

And, of course, pollution can be naturally occurring as well as induced by man. For example, there are many instances of naturally occurring salts or organics occurring in streams. But our main concern is with that induced by man's activity.

Environmental quality seems to me to be a substantially broader concept. It encompasses psychologic as well as physical, biologic, or economic impacts on man. Billboards or trash on the highway, extinction of a bird species, or destruction of esthetic values of wildlands may not degrade the utility of the resource, yet may decidedly lower its quality in the eyes of some or of many. The weeds in my lawn or the unkept farm fence may be "visual pollution", but they do not seem to me to be pollution in the same sense as automobile exhaust fumes in the air, processing wastes in a stream, or salt laden drainage waters from an irrigation project.

It has been my privilege over the past several months to work with a committee in USDA in an attempt to identify the most important environmental issues facing agriculture. Without boring you with all the details, I would like to summarize what seem to have evolved as the major critical environmental issues relating to agriculture.

The most obvious issue, of course, is pollution — the many forms of degradation of the quality of our natural environment. You know the sources as well as I — agricultural chemicals, production and processing wastes, sediment, sewage, smoke, solid wastes, etc.

I'll return to this issue a bit later. But I would like first to point out three other sets of issues that demand equal or greater attention as we strive to retain or improve environment quality. There are resource planning and use, development, or redevelopment of our rural areas, and the supply and safety of our foods.

The base resource is the land with its associated water and air and the life forms it supports. Agriculture, forestry, and other rural interests are the stewards and managers of over 90 percent of the nation's land. This land provides most of our food, fiber, and shelter needs. In addition, it is the source of most of our water supply and supports the bulk of the living things around us. Further, a large share of the air breathed in our cities first sweeps across our rural landscape.

So, first of all, it is urgent that agriculture and forestry devote major attention to improving resource planning and especially to optimizing land-use patterns. We should include lands in the urban-rural interface as well as those in purely rural areas. Our prime objective should be to retain or improve environmental values — physical, biological and psychic. And a major part of this thrust should be retaining a large share of our best remaining lands in production agriculture.

Secondly, we must devote increased attention to developing economic and social opportunities in rural America. In particular, we must get on with the job of identification and capitalization of job opportunities, and delivery of housing and community services to enhance the quality of rural living.

And finally, we must continue and intensify our efforts to assure an abundant food supply of high quality and assured safety.

These, then, are the major roles and responsibilities of agriculture and forestry in assuring a quality environment, now and in the future:

To assure orderly resource planning and use,

To identify and assist in rural development,

To assure an abundant, high quality, and safe food supply, and

To control or abate the degradation of the natural environment.

I'd now like to elaborate a bit on the last of these — the environmental degradation or pollution issue. What are the key problems for agriculture and what should we be doing about them?

Sediment is alleged by many to the most significant agriculturally related pollutant. And, in the final analysis, this may be true. Certainly in terms of volume, tonnage, or ubiquity, it is the biggest. And perhaps it is the most expensive, both in terms of damages and in terms of control costs.

I shall not attempt to resolve whether it is the biggest problem or not, but it is a large and difficult one. We have worked at it for a long time, and I would judge we must continue to do so. We need better erosion and sediment control knowledge, and we need to work harder at its application. Much of our technology on the subject is proving to be useful to other segments of society — the subdivision developer, the highway builder and the industrialist. We need to continue to help in application of this technology outside as well as in agriculture.

Probably the most publicized pollution problem in agriculture in recent years is agricultural chemicals. "Pesticides pollution" has become a household phrase, and one we couldn't ignore if we wanted to. And we haven't. Perhaps we have been overly defensive (or perhaps over-sensitive) in agriculture on this question, but that isn't all bad either. We have needed pesticides and we shall continue to need them, probably indefinitely, as we meet our food and fiber production responsibilities. So we must play what might be considered the advocate role.

But let's be sure of what we are advocating. We should work toward limiting pesticide use to those cases where effective alternates are not available. In particular, we should limit both instances and amounts of use to documented minimal requirements. We must use integrated chemical and nonchemical controls wherever possible. And we must continue and intensify the research for viable alternatives to pesticides for control of pests.

As to other chemicals, we have faced and I'm sure we shall continue to face some tough questions as we go down the road. Toxic elements such as mercury, copper, and arsenic, as well as common fertilizer elements, will come under increased scrutiny. It is urgent that we generate complete and defensible data on the behavior of these and other chemicals used in agriculture. We do not have such data, and I doubt that the current expanded research will generate it fast enough. And we must apply what we already know. In the whole chemicals area we can by no means continue to apply the principle "if a little is good, a lot is better." Whether it be pesticides, fertilizers, or chemicals used in processing, it is in our interest and that of the general public to get the facts and to apply them.

How about wastes — human, animal, processing, and production wastes? We know a good bit about how these behave in the natural system when they are reasonably dispersed. We know that rather serious problems result when these natural systems are overloaded, as has occurred in many of our water supplies. And the sanitary engineers have developed substantial expertise in managing concentrated organic refuse.

But we haven't really scratched the surface in learning to capitalize on utilization of these wastes as economic resources. How can they be incorporated in land management schemes to maximize their potential benefits — benefits such as plant nutrients or improving soil physical properties — and at the same time dispose of the wastes in an economic and effective manner? Or, alternatively, are there other recycling possibilities, such as animal feeds or building materials, to which such materials can be directed? We need substantially increased research on these problems. And again we need to increasingly apply what we already know.

A waste problem worthy of special note is sewage. We have already reached or are approaching the end of the road in disposing of sewage by conventional septic or sewage treatment and disposal methods. Water sources for disposal are either taxed or overtaxed, and increasing concentrations of sewage loads, both in metropolitan and in rural areas, demand alternative disposal sinks.

Since the source of most of our sewage load is the land, it seems most appropriate to consider the land rather than the air, as a prime alternate sink for these wastes. This approach likely offers some economic as well as ecologic advantages as an alternate to water systems. So I believe we in agriculture must offer our resources, our technology and our cooperation to our urban friends as we research together for viable urban waste disposal alternatives. Research and demonstration efforts are urgently needed to assess the most functional alternatives in this vital area.

I could go on itemizing pollutants and our involvement with them — but there have been reams written that document the case better than I can. The main points I hope I've made and wish to leave with you are:

(1) We are deeply involved with a broad spectrum of environmental issues.

(2) We know far too little about most of them — we need greatly improved knowledge to cope with these problems.

(3) We must apply what we do know with greater intensity in the interest of all of us, both now and in the future.

SESSION I: R. D. Rouse, Agricultural Experiment Station, Auburn University, Auburn, Ala., Chairman

UPGRADING AGRICULTURAL RESIDUES AND THEIR USES

by
Paul E. Kifer
Ralston Purina Co.
St. Louis, Mo.

INTRODUCTION

Agricultural residues are the leftovers from an animal agricultural operation, with the primary products being meat, milk, and eggs. As in the case with any leftovers, these residues can be treated in a variety of ways, and the treatments determine their subsequent value and potential for reuse.

The residues fall conveniently into two classes: (a) Those left by the animals during the normal growing period and referred to usually as "animal wastes"; and (b) those left from the animals after the preferred portions are separated for human food use in a packing house operation. These latter materials are usually considered byproducts and have been used in a wide variety of ways.

The purpose of this paper is to review the current situation with regard to the production and reuse of some of these residues, point out opportunities for upgrading, and propose some possibilities for the future.

Animal Wastes and Their Uses

A recent report from the Stanford Research Institute which deals with trends in animal production states:

> "Perhaps the greatest single problem in mass production facilities is that of waste disposal. Poorly managed waste causes toxicity within facilities, while seepage causes nitrate poisoning of water supplies . . . Recycling sterilized waste for its nitrogen content could reduce the toxicity problem and increase feed efficiency.
>
> Air pollution is also a growing problem. Odor control will become crucial in communities near mass production facilities.[1]

Interestingly enough, this is just about all of the information dealing with this topc that appears in the entire report.

Animal wastes have always been with us, but when operations were relatively small and dispersed these residues just tended to disappear. As animal production has become more concentrated, the residues have increased in proportion. The figures connected with these changed circumstances have been quoted frequently enough to be familiar to all:

> "More than 1.7 billion tons of animal wastes are produced annually."
>
> "A single large poultry operation may produce as much as 5 tons of waste per day."
>
> "A 10,000 head feed lot will produce 260 tons of waste per day."

There are several alternatives available as means of disposal, such as: Burning, burying (or hiding by some means), treating as sewage, and recycling.

The latter method — recycling — involves consideration of these materials as a potential resource rather than as a disposal problem. Thus, they become a sort of "agri-ore" — a raw material to be mined accordingly and upgraded. Consideration should be given to cost/benefit ratios and a combination of processing methods selected which permit some economic recovery and which insult the environment the least.

Recycling of processed animal wastes as a component of animal feeds has been studied by various research groups. This seems a reasonable approach. Shown below is an estimate of the tonnage of some of the major types of livestock and poultry feed sold annually. Recycling of processed animal wastes at a 5% level, in these particular classes of feeds, would remove approximately 2.7 million tons of dried waste (or 10.8 million tons on an "as is" basis) from the environment — at least temporarily.

Type	Estimated Tons/Year
Laying hen[1]	13,500,000
Dairy	12,000,000
Beef	9,600,000
Swine	9,500,000
Broiler	9,300,000

[1] Includes replacement birds

---

[1] *Trends Affecting Animal Husbandry.* SRL. LRPS Report #373, April 1969.

Some recently reported work at Michigan State University[2] involved feeding of various levels of dried poultry waste. A portion of their work with broilers is summarized below.

	Control	Dried poultry waste 5 Percent	20 Percent [2]
Av. Wt. grams (4 weeks)	606.3	606.6	622.8
Feed/ Grain	1.82	1.85	1.92

---

[1] With 4 percent added fat.

These people have also conducted feeding trials with laying hens, and some of the results of two trials are summarized below.

Trial 1	Control	Dried poultry waste 10 Percent
Production percent	58.24	61.62
Pounds feed/ doz. eggs.	4.30	4.32
Trial 2		
Production percent	74.05	73.38
Kilos feed/ doz. eggs	2.11	1.91

At higher levels (above 10 percent), production and feed efficiency were affected, but it is possible that this was due to a lowering of the energy content of the ration as was noted in the experimental work with broilers. Egg weights, shell thicknesses, and Haugh scores were not affected. No significant affects on tastes were noted by a taste panel.

Several interesting things have been reported as a result of continuing studies. Poultry waste has been recycled through the same flock nine (9) times. Another observation has been that the fresher the manure, the higher the protein level in the dried poultry waste product. As a result of this study, these researchers are now collecting and drying every 7 days.

Additional work by the Michigan State group has included feeding trials with various levels of dried poultry waste in rations for beef cattle, dairy cows, and sheep. Results have been generally favorable.

These studies are presented here as an example of upgrading. Certainly a great deal of work remains to be done.

Product characteristics will need to be determined. Basic information will be needed on nutrient content and availability. Equipment will have to be developed to allow local and frequent processing. Equipment and processing methods will have to ensure that bacterial control is achieved and that recontamination following processing is prevented.

Animal Byproducts and Their Uses

The other "leftovers" are the byproducts of a modern poultry-processing plant or meat-packing plant as a part of the production of food for human consumption.

Some of these byproducts are washed and frozen for subsequent use in pet foods and to a lesser extent now for milk feeding). They are also rendered, the fat expressed if needed, and the resulting meal and fat used separately as ingredients in animal feeds.

Some specific examples of byproducts upgraded in this manner and in widespread use by the feed industry are:

Meat meal
Animal fat (poultry fat)
Blood meal
Feather meal
Poultry byproduct meal
Various byproducts of the dairy industry

Within the limits imposed by the processing these byproducts have received, they all serve a useful purpose in animal-feed formulations. Processing methods developed and used have sometimes been a compromise between ease of production and quality of end product — with the solution more often resolved in favor of ease of production.

The quantities of raw materials available as byproducts for processing and upgrading are substantial. The following shows the quantities available from a poultry processing plant.

Typical broiler processing plant

80,000 birds[1] per day

	Pounds
Offal (heads, guts, feet, etc.)	42,000
Feathers	28,000
Blood	11,200

---

[1] Average live weight 3.5 pounds

---

[2] *Poultry Pollution: Problems and Solutions.* Michigan State University Research Report 117, July 1970.

There are in excess of 2,500,000,000 broilers produced in this country in a year. The byproducts from these birds represent a sizable and valuable resource.

Typical information on cattle and swine are as follows:

Typical cattle operation

1,000 head[1] per day

	Pounds
Offal	220,000
Blood	42,000

---

[1] Average live weight 1,000 pounds.

Typical swine operation

3,200 head[2] per day

	Pounds
Offal	51,200
Blood	19,200

---

[2] Average live weight 200 pounds.

Processing and use of these materials as feed ingredients represents a form of highly desirable upgrading, since otherwise these would have to be disposed of as a sort of agricultural garbage. Approximately 35 million cattle and 50 to 60 million swine are slaughtered annually.

Further upgrading is a possibility. Poultry byproduct meal, for example, can be made into a much better product than is generally offered to the feed industry, shown below.

Poultry Byproduct Meal

	Typical	Possible
Protein	55 percent	65 percent
Fat	15	12

These improvements result entirely from improving the operations in the rendering plant, operating the equipment in a uniform manner, and modifying cooking times.

Feather meal is a product which is high in total protein. It is, however, of limited use in animal feeds. Feather meal protein is not highly available to an animal. The processing techniques used result in loss of cystine, further reducing the value of the protein.

Here is an opportunity. Upgrading could improve the value of the feather meal. We need a process for converting feathers to a more digestible product. We need to improve the nutritional properties by a better processing method — one that will not destroy critical amino acids. Such a process could probably be adapted to recover useful and valuable protein from the 50 to 60 million pounds of hog hair available annually and not now in productive use.

In a similar manner, meat meal, blood meal, and other byproducts produced today could be upgraded and made more valuable and useful.

Considerations for the Future

We are in the food business and should consider our agricultural production systems as being essentially food-oriented. As a part of operating a complete system, we should be designing techniques and processes for the safe reuse of byproducts resulting from these systems.

Adequate consideration has to be given to the cost/benefits ratio. Some animal wastes and some byproducts will not be worth processing for recycling. In this instance, disposal by the most complete and economical means becomes a necessity.

Along with this is a need for continuing education of personnel in regulatory agencies to the desirability and safety of recycling byproducts.

Summary. — Agriculture, in the immediate future, must learn a great deal more about the overall management of the residual products from animal-oriented operations. We must recognize that the cost of production will also include the cost of disposal and this, in turn, will require the development of profitable means of disposal. To do this effectively will require:

(a) Development and use of new technologies;

(b) New and improved facilities;

(c) New and improved management techniques;

(d) New and improved methods for converting byproducts into useful products;

(e) New and improved methods for disposal of those residues that cannot be converted into useful products;

(f) The establishment and enforcement of adequate and scientifically justifiable standards for these products; and

(g) New and improved criteria for evaluating processes and products.

DESTRUCTION OF FUNGI BY LOW CONCENTRATIONS OF METHYL BROMIDE

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(Presented by W. H. Lee)

SUMMARY

Studies with inoculated food samples showed that many strains of fungi were killed by 30 to 45 mg./1 of methyl bromide. In one study, $\sim 10^5$/g. Aspergillus parasiticus spores inoculated in rice were killed by 90 mg./kg. of methyl bromide of 180 days at 28° C. In another test, $\sim 5 \times 10^4$/g. of the heat resistant Byssochlamys fulva asci inoculated in tapioca starch were destroyed by 240 mg./kg. of methyl bromide in 30 days at 28° C. Storage of crops with low concentrations of methyl bromide may have the unique potential of destroying fungi, insects, and rodents.

INTRODUCTION

Food is in short supply, and yet each year an estimated 10 percent of the world food crop, or 100 million tons, is destroyed by fungal, insect, and rodent attacks (1). In addition, the mycotoxins in some moldy crops are a serious hazard to animal and human health. Modern grain storage relies on low moisture and temperature to prevent fungal spoilage. However, the fungi are not destroyed in storage, and they can initiate spoilage later under proper conditions. Presently there is no practical method to destroy fungi in crops.

The fungicidal activity of methyl bromide (CH_3Br) was discovered by Newhall and Lear in 1948 (5). Wensley (7) reported that about 90 mg./1. of CH_3Br killed 99 percent of soil fungi in 24 hr. and 94 percent of the soil bacteria in 96 hr. CH_3Br is being used to control fungal contamination in mushroom compost (3). Srinivasan and Majumder (6) reported that $\sim$140-150 mg./kg. of CH_3Br is widely used for insect fumigation in grains. Therefore, it is of interest to explore its fungicidal effect at the established bromide residue tolerance of 50 to 200 p.p.m. for grains and oil seeds (2).

MATERIAL AND METHODS

Some of the methods and results described here have been published already (4). Figure 1 is a schematic diagram of the CH_3Br addition procedure. Inoculated samples to be tested were placed inside a Mason jar. CH_3Br was flushed through a 10-ml. Hamilton backfill and gastight syringe. The backfill valve was shut off and a known volume of CH_3Br was added into the Mason jar. The jar was immediately sealed.

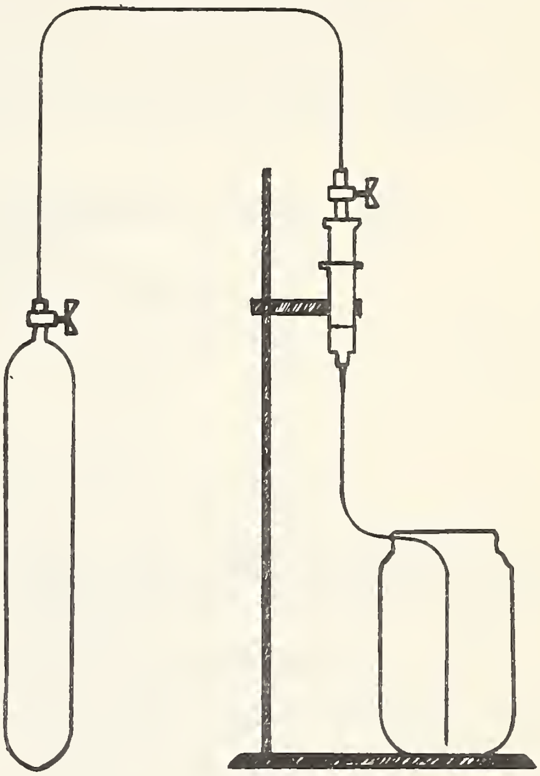

Figure 1. Schematic diagram of small scale CH_3Br test procedure

RESULTS

Sensitivity of microbial cultures in CH_3Br was tested by exposing inoculated agar slants to various levels of CH_3Br in a Mason jar. Growth of the microorganisms was observed through the glass jar. By this technique we found that Alternaria tenuis, Aspergillus ochraceus, A. parasiticus, Byssochlamys fulva, Fusarium graminarium, Penicillium rubrum, Rhizopus species and Saccharomyces cerevisiae were killed by 15 to 30 mg./1 of CH_3Br. On the other hand, Salmonella senftenberg, S. typhimurium, and Clostridium botulinum 62A spores were resistant and survived 45 mg./1. of CH_3Br for 30 days. Bacteria are resistant to low concentrations of CH_3Br.

Next we tested the effect of water activity on the fungicidal action of CH_3Br. About 5 x 10^4/g. A. parasiticus spores and $\sim 10^5$/g. of P. rubrum spores were inoculated in 10 g. of rice, which was adjusted to various moisture levels. We found that the spores survived in all the untreated samples but were all killed by 30 to 45 mg./1 of CH_3Br in 5 days or more (4). Note that few spores persistently survived in the sample with only 5-percent moisture and very low water activity.

We then tested 500 g. inoculated rice to determine the bromide residue concentrations. Bacteria were resistant and spoiled the rice with 20 percent moisture. Bacteria did not grow in the rice with 15 percent moisture, and $\sim 10^5$/g. of A. parasiticus spores were killed by 90 mg./kg. of CH_3Br in 180 days (table 1). Bromide residue analysis by Dow Chemical Co. of 4 replicates showed that 90 percent of the CH_3Br was recovered from the rice samples. The rice did not develop off color or odor in 6 months. Unlike that of the 10 g. samples, the spore count of the 500 g. control sample without CH_3Br also dropped 99.5 percent in 6 months. Sealing up may favor the destruction of the fungi.

B. fulva asci sometimes survive the heat processing of canned acid foods and cause spoilage. We are still testing the destruction of B. fulva asci mixed in tapioca starch with CH_3Br. The starch sample tested in table 2 had only 9 percent moisture and 0.36 water activity. We suspect few asci survived in the starch treated with 120 mg./kg. of CH_3Br due to low moisture. This experiment will be repeated with inoculated tapioca starch with higher moisture.

Table 1. Destruction of Aspergillus parasiticus spores in 500 g. of rice (15 percent H_2O) with methyl bromide at 20°

Methyl bromide (mg/kg.)	Bromide residue (p.p.m.) Total	Net	Survivors/g. 0	60	120	180[1] Days
0	71	0	90,000	15,000	850	415
60	116	45	90,000	230	37	13
90	148	77	90,000	2	1/3	0

1 The photograph of these samples is presented in the following publication: Lee, W. H. and Riemann, H. 1970. Destruction of toxic fungi with low concentrations of methyl bromide. Appl. Microbiol. 20: 845-846.

Table 2. Destruction of heat resistant[1] Byssochlamys fulva asci in 200 g. of tapioca starch by methyl bromide

Methyl bromide (mg./kg.)	Survivors/g. 0	30	60	90	120 Days
0	70,000	70,000	120,000	–	17,500
60	70,000	11,000	4,700	–	450
120	70,000	30	9	70	45
238	70,000	0	0	0	–

1 Samples heated to 75° 10 min. before plating on agar.

DISCUSSION

The above results indicate that many fungi are sensitive to low concentrations of CH_3Br. CH_3Br at 90 to 120 mg./kg. may eliminate all fungi from food crops. The fungistatic concentrations may even be less. Additional research is necessary to develop a practical storage system.

Corn, peanuts, rice, and wheat will have to be tested separately because of possible variations of CH_3Br penetration, deterioration, and organoleptic changes. We can test many variables such as CH_3Br concentration (0 to 200 mg./kg.), water activity (0.85 to 0.65), and temperature (5° to 37°) in 1/2 to 1 kilogram samples with the same test procedure used before (4). The sensitivity of many other toxic fungi to CH_3Br can be tested at the same time.

An ordinary 55 gallon steel drum can be used to test 100- to 150-kilogram samples (fig. 2). Methyl bromide is released into the loaded drum by turning the screw to break a glass ampoule of CH_3Br. A 3.5 ml. ampoule of CH_3Br applied to 100 kilograms of grain will

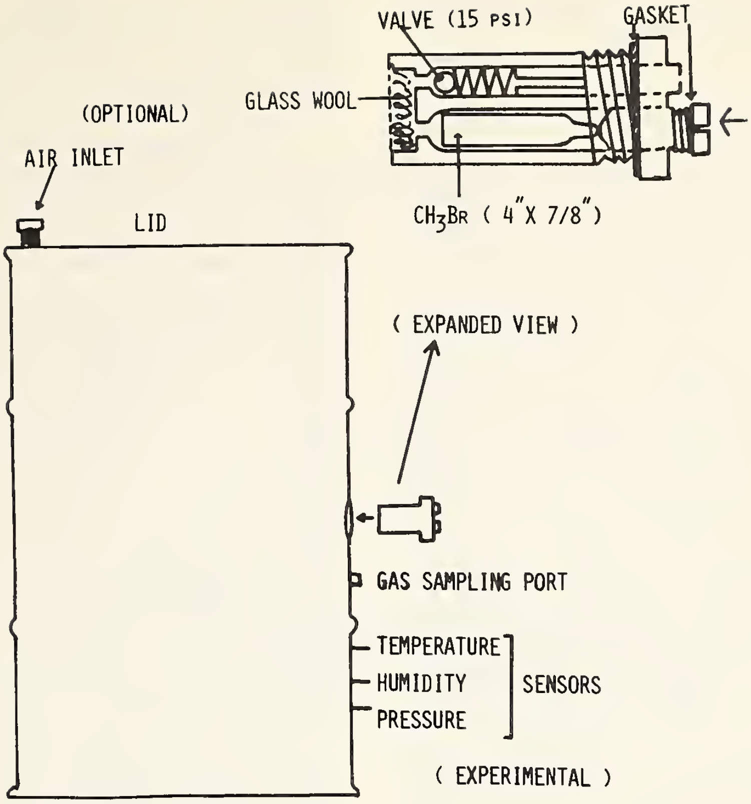

Figure 2. Schematic diagram of a 55 gallon CH_3Br storage container

yield a concentration of 60 mg./kg. of CH_3Br. Dispensing CH_3Br in small glass ampoules will eliminate dose errors and dangers of CH_3Br poisoning. Larger storage units with internal circulation can be built if the system works. If grain is stored in a sealed rodent-proof unit with CH_3Br, the crops are safe from fungi, insects, and rodents. The system may be especially useful in long-term storage of commodity crops.

Literature Cited

1. Food and Agriculture Organization of the United Nations. 1969. Bigger crops and better storage. The role of storage in world food supplies. World Food Problem No. 9. FAO, Rome Italy.
2. Frear, O. E. H. 1969. Pesticide handbook-entoma, p. 62. College Science Publ., State College, Pa.
3. Hayes, W. A. 1969. Methyl bromide as an after-crop sterilant. Mushroom Growers Assoc. Bull. No. 234: 240-243.
4. Lee, W. H. and Riemann, H. 1970. Destruction of toxic fungi with low concentrations of methyl bromide. Appl. Microbiol. 20: 845-846.
5. Newhall, A. G. and Lear, B. 1948. Soil fumigation for fungus control with methyl bromide. Phytopath. 38: 39-43.
6. Srinivasan, K. S. and Majumder, S. K. 1961. Effect of some volatile chemicals on the microbial spoilage of moist Kafir corn (*Andropogon sorghum*) under air tight storage. Cereal Chem. 38: 529-535.
7. Wensley, R. N. 1954. Microbial studies of the action of some selected soil fumigants. Can. J. Bot. 31: 277-308.

PROGRESS ON CONTROL OF AFLATOXINS AND ELIMINATION FROM AGRICULTURAL PRODUCTS

by
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(Presented by F. G. Dollear)

You may be surprised to find my assigned topic today "Progress on Control of Aflatoxins and Elimination from Agricultural Products" on a program whose theme is "Agricultural Research and Pollution." However, just as the concept of pollution has been extended from the conventional media of air and water to include sound, heat, and light, so now it seems entirely appropriate to consider contamination of foods and feeds by metabolites of the ubiquitous fungi Aspergillus flavus or parasiticus as another pollution problem.

I would like to take just a couple of minutes to provide some orientation. Problems associated with the presence of aflatoxin in feedstuffs arose almost simultaneously in England and in the United States 11 years ago. In England, in the course of a few months in 1960, more than 100,000 young turkeys died of what was then unknown causes. Eventually the cause was traced to the presence of an imported peanut meal in the rations, and specifically to a toxic material produced by the very common mold Aspergillus flavus in that peanut meal. The toxic material was then given the name A FLA TOXIN in view of its origin. Now we have an interesting coincidence. In April of 1960 a shipment of live rainbow trout from a commercial fish hatchery in Idaho was stopped at the California border for a routine entrance inspection and examination revealed a high incidence of hepatomas (liver cancer). The difficulty was subsequently attributed to a cottonseed meal, contaminated with aflatoxin, in the ration of the hatchery trout. Aflatoxin has been characterized as among the most potent known carcinogens in some animal species, and the rainbow trout appears to be the most sensitive.

As aflatoxin is carcinogenic to some animal species, there is no tolerance for aflatoxin in any food or feed. There is no way to establish an acceptable tolerance for it. The concept of zero tolerance is a very difficult one, and in practice the Food and Drug Administration (FDA) has issued guidelines which, essentially, call for diversion from food and feed channels of any lot if routine examination reveals aflatoxin levels of 20 p.p.b. or more. Also, dilution to reduce levels to below 20 p.p.b. is not condoned. Under favorable circumstances, aflatoxins can be detected at levels distinctly below one part per billion (p.p.b.). One p.p.b. is equivalent to 1 second in 32 years.

We now know that the mold Aspergillus flavus produces not just one toxin but many toxins. At least a dozen different chemical compounds that may be produced by the mold are now designated aflatoxins. Their structures are shown in figure 1. All 12 are very closely related in chemical composition and structure. Many millions of dollars have been spent on research on aflatoxins, and well over a thousand scientific papers dealing with the aflatoxins have been published. As a result, we now know much more about aflatoxin than we did ten years ago, and research is continuing, but I have to admit at the outset that we do not yet have a complete solution to the aflatoxin problem. In my discussion I shall concern myself with three aspects: First, control by prevention of development of aflatoxin; second, removal of aflatoxin and third, destruction of aflatoxin.

What can be done in the way of prevention? The first step is recognition and awareness that the threat exists. A major problem is motivation of untrained personnel at all stages of culture, harvest, transportation, storage, and processing. The Agricultural Research Service of the United States Department of Agriculture has issued a special report entitled "Preventing Mycotoxins in Farm Commodities" which should be very helpful. You can get a copy by writing to us at the Southern Marketing and Nutrition Research Division for ARS 20-16. The report emphasizes the importance of good farm management practices and notes that mold prevention should begin with proper planting and growing of the crop. The Department has issued Farmers' Bulletin No. 2238, Guidelines for Mold Control in High-Moisture Corn. You can get a copy by writing to the ARS Information Division, USDA, Hyattsville, Md., 20782 for a copy.

A warm temperature and high moisture are the most important conditions contributing to mold. Recommended safe moisture levels will vary with the crop and with other conditions of storage, but it should be emphasized that they refer to all the seeds in a lot and not just the average moisture content. Provision of clean, dry, adequately cooled and ventilated storage is important, and good sanitation is essential to minimize mold contamination during storage and processing. The use of antifungal agents to control fungal infestation has been the subject of much study, but thus far there appears to be no fungicidal treatment that has been successful for large-scale application, despite the considerable effort that has been exerted in this area. Genetic approaches that may result in resistance to elaboration of aflatoxin are under investigation, but this is a long-term approach and no lines have yet been released.

Damage and contamination with aflatoxin may occur despite the most strenuous efforts directed at prevention. Then other approaches must be considered, fully recognizing that they are to be applied only if preventive measures have failed and not as an alternative to good cultural and storage practice. I shall discuss two approaches: (1) removal, and that includes removal by mechanical means and by use of solvents, and (2) destruction.

It is obviously desirable to identify contaminated lots of any product as early as possible in the marketing chain to minimize contamination of other uncontaminated lots. The peanut industry has had good success in identifying contaminated lots by examination of the

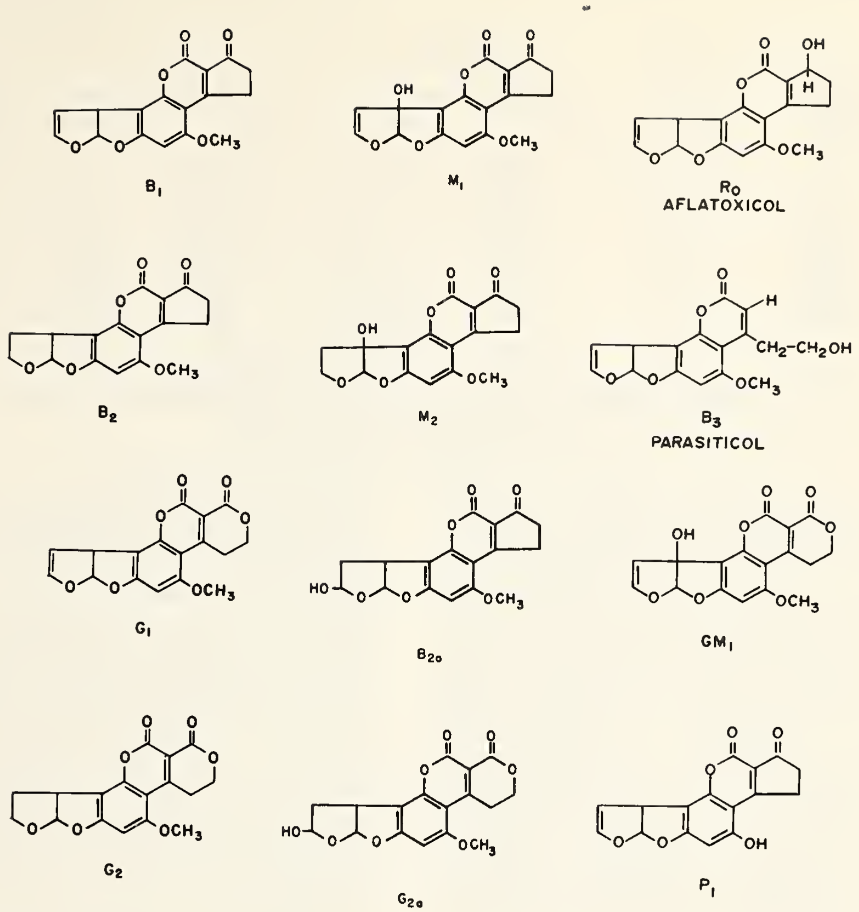


Figure 1. Structures of the aflatoxins

damaged kernels of the grading sample of farmers stock peanuts for visible Aspergillus flavus, using a stereomicroscope under 25X magnification for examination of suspect kernels. If the mold is detected at this stage, the lot must be diverted to nonedible use. This is not an infallable test, but it has been a tremendous aid to the peanut industry. Other industries are not so fortunate. In the case of cottonseed, such a test is not feasible, but a correlation has been reported between the presence of aflatoxin and of a certain greenish fluorescence when unweathered fuzzy cottonseed or lint cotton is examined under ultraviolet light. This fluorescence was observed before aflatoxin was recognized and has been called "cat eye." Unfortunately, the correlation here is nowhere nearly as good as that found with peanuts and visible A. flavus, but it may be useful in some instances in detecting certain lots of contaminated cottonseed and thus preventing accidental contamination of much larger quantities of high quality seed.

It has been our experience, and that of others who have reported, that the vast majority of the aflatoxin in contaminated cottonseed and peanuts usually resides in a relatively small proportion of seed, generally less than 1 percent. This affords an exceptional opportunity for effectively yet economically reducing the aflatoxin content by mechanical removal of those few seeds or kernels that may have become contaminated. Physical separation methods are being used successfully in the peanut industry. The peanut industry practiced culling to select only high-quality peanuts for food products long before the discovery of aflatoxin. This culling is typically accomplished by screening at shelling plants, by removing discolored kernels by hand sorting, or by electronic sorting devices which examine each kernel separately and either pass or reject it on the basis of color when scanned by a photoelectric cell. Data in table 1 show what can be done by air classification and electronic sorting. With the recognition of the aflatoxin problem, this culling of peanuts for food products has been intensified.

Table 1. The distribution of aflatoxins B (p.p.m.) in Natal common-type kernels

Sample (800 kg.) no.	Original sample	Air separated rejects	Size graded		Color sorted			
					Medium		Small	
			Medium	Small	Accept	Reject	Accept	Reject
1	0.2	0.3	0.005	0.26	<0.005	0.1	<0.005	0.1
2	.08	.13	.08	.1	< .005	.4	.005	.2
3	< .005	.08	< .005	< .005	< .005	.08	< .005	.08
4	.005	.08	< .005	.2	< .005	< .005	< .005	< .005
5	.005	.2	.13	< .005	< .005	< .005	< .005	.08
6	< .005	.13	< .005	< .005	< .005	< .005	< .005	.12
Mean	0.05	0.15	0.04	0.09	<0.005	0.1	<0.005	0.1

Source: Pattinson, Crowther, and Noubey. Trop. Sci. 10(4): 212-221. 1968.

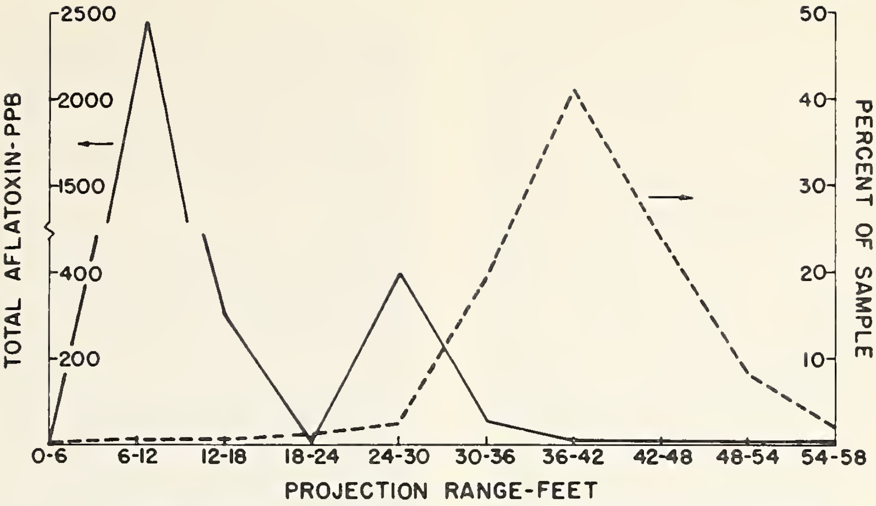
The peanut industry has voluntarily adopted a Code of Good Practices that calls for examination of every operation from purchasing through packaging. The Code provides guidelines and specific suggestions. It was originally adopted in 1964 and has been revised and updated at least once each year since then. You can get a copy by writing to the National Peanut Council, 1120 Connecticut Ave., Washington, D.C. 20036. The peanut industry has done an outstandingly effective job in safeguarding from the danger of aflatoxin, and this has had the salutary effect of providing the American consumer with the highest quality peanuts and peanut products in history. Similar improvements have been accomplished for brazil nuts.

Aflatoxin contaminated cottonseed cannot be distinguished from uncontaminated cottonseed in ordinary light, but use of the fluorescence under ultraviolet to separate contaminated cottonseed has been proposed. It has also been suggested that it might be possible to take advantage of certain other physical characteristics of contaminated cottonseeds to separate them. Back in 1956, Holzenthal and others here in New Orleans showed that cottonseed can be separated into fractions of different quality, i.e., free fatty acid content, light and decayed seed, foreign matter, etc., by use of mechanical projection devices. The highest quality seed are projected farthest because of their ballistic characteristics. Ten years later, results were reported on two tests to separate aflatoxin contaminated cottonseed by projection. Some of the results are shown in figure 2. In one trial, shown on the upper half of this figure, more than 63 percent of the aflatoxin was concentrated in about 6 percent of the seed, and about 35 percent was concentrated in 25 percent of the seed. Although the separation was not as good as might be desired, it did indicate potential for separation of aflatoxin-contaminated cottonseed by this procedure. Unfortunately, in another test with another lot of seed, little or no segregation was achieved. The results of this second test are shown on the bottom half of the figure. The latter seed was obviously more uniformly contaminated with aflatoxin. That is where the situation stands now, except that we have just received delivery of a Zig-Zag separator, and we have acquired several lots of aflatoxin contaminated cottonseed. We plan very soon to conduct additional tests to determine the feasibility of separating aflatoxin contaminated cottonseed in this way.

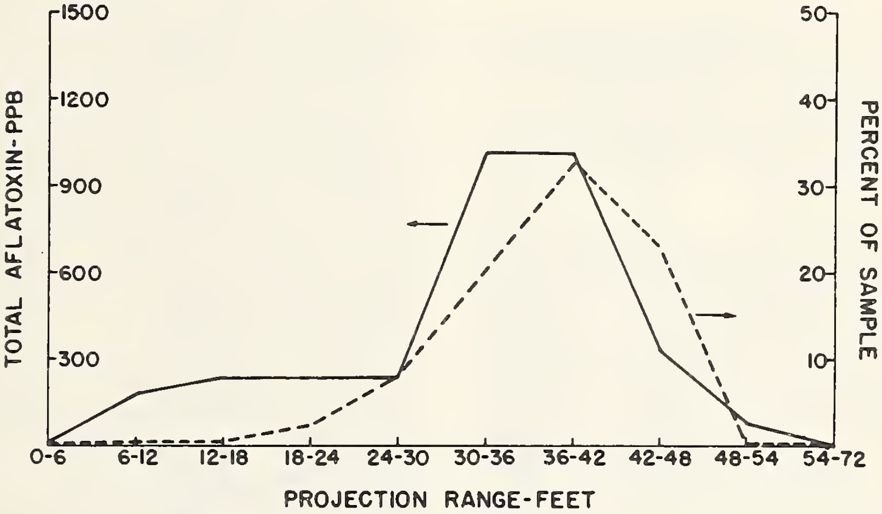
Now let us consider removal of aflatoxin by extraction.

Current processing practices, either mechanical expression or extraction with commercial hexane, leave in the defatted meal the vast majority of any aflatoxin that may be present in the seed. The crude oils obtained may contain various amounts of aflatoxin, depending upon the raw material and the conditions used in processing. However, it has been established quite conclusively that conventional processing, i.e., refining and bleaching of vegetable oils, removes essentially all the aflatoxin.

Aflatoxins are not soluble in the hydrocarbon solvents that are usually used in processing oilseeds, but they are readily soluble in many polar solvents. A solvent system of acetone, hexane, and water was found to remove aflatoxin readily and quantitatively from ground peanuts or peanut meal while removing relatively little extraneous material other than oil. A solvent system composed of acetone-hexane-water has been proposed for extraction of cottonseed flakes to produce cottonseed oil and meal commercially. Aqueous acetone may also be used as a selective solvent. A recent report concludes, and I will quote, "Aflatoxin can be removed or significantly reduced in cottonseed and peanut meals by extracting with a tertiary



Aflatoxin in Projected Cottonseed (Assay of Composite, 40-80 PPB)



Aflatoxin in Projected Cottonseed (Assay of Composite, 750 PPB)

Figure 2. Aflatoxin in projected cottonseed

solvent system of 54 percent acetone, 44 percent hexane, and 2 percent water (by weight) or a binary solvent system of 90 percent acetone and 10 percent water (by weight). The tertiary solvent system simultaneously removed oil and aflatoxin from prepressed cake containing 12 to 15 percent oil, resulting in residual lipids content of approximately 1 percent".

Extraction of cottonseed flakes with acetone containing 25 to 30 percent water has been reported by Pons and Eaves of the Southern Marketing and Nutrition Research Division to remove essentially all the gossypol, most of the free fatty acids, half of the raffinose, and negligible quantities of neutral oil and protein, yet to be effective for the removal of aflatoxin. Reduction of aflatoxin by 96 to 98 percent was reported. The residual, essentially full-fat, product now practically free of any aflatoxins that may have been present, can then be processed for oil removal by any conventional means. This solvent system is potentially applicable to peanuts and other oilseeds also.

Removal of aflatoxin from oilseed meals by aqueous alcohols has been studied, and typical results are shown in figure 3. Extraction with 80 percent aqueous isopropanol at 60° C. resulted in complete removal of aflatoxin from cottonseed and peanut meals in six passes. Extraction with the isopropanol-water azeotrope (87.7 percent isopropanol by weight) was less effective, resulting in only about 80 percent reduction of aflatoxin content in six passes. Anhydrous isopropanol was ineffective. Good reduction in aflatoxin content of contaminated cottonseed and peanut meals was also obtained by extraction with 95 percent ethanol. Solvent extraction systems have the advantage that

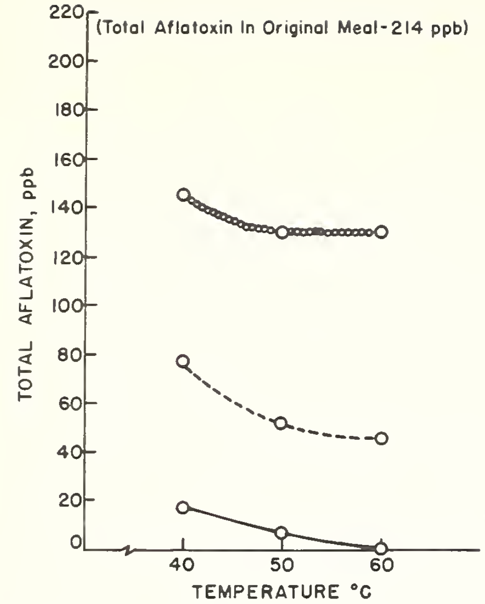


Figure 3. Effect of solvent and temperature on extraction of aflatoxins from cottonseed meal using 6, 15-minute solvent passes. —— 100 percent isopropanol; ——, isopropanol-water (87.7 percent isopropanol) azeotrope; ——, 80 percent aqueous isopropanol

under suitable conditions they can remove essentially all the aflatoxins with little likelihood of forming from the aflatoxins products having adverse physiological activity and without appreciable reduction of protein content or of its nutritional quality. On the other hand, there is the cost of additional processing, the need for special extraction and solvent recovery equipment, the loss of some water soluble components of the residual meals and provision for their disposal.

Finally, there remains the possibility of degrading, destroying, or otherwise inactivating the aflatoxins, for example, by heat, chemical, or biological methods. Any such treatment must, of course, not only inactivate the aflatoxins but also retain the nutritive value of the material processed and leave no harmful residues.

Aflatoxin is very stable to heat. A detailed study of the effect of heat and moisture on aflatoxins in oilseed meals has been made, and some results with cottonseed meal are shown in figure 4. Treatments at 60° and 80° C. resulted in very little reduction of aflatoxin, but definite reduction was obtained at 100°. The effect was enhanced by increasing times of heating and by increasing moisture contents. About 80 percent reduction in aflatoxin was achieved by heating for 2 hours at 100° C. and 20 percent moisture. It was concluded that although increased moisture content results in increased destruction of aflatoxin, heat and moisture alone do not supply a very satisfactory method to inactivate or remove aflatoxin from oilseed meals.

Comparison of the aflatoxin contents of individual raw peanut half-kernels and of the corresponding half kernels after dry roasting under conditions simulating those that might be used for the production of peanut butter indicated significant reduction after roasting. Thus an additional margin of safety is afforded for such roasted products.

Ciegler and his coworkers at the Northern Marketing and Nutrition Research Division in Peoria have investigated microbial detoxification of aflatoxin. Approximately 1,000 organisms representing yeasts, molds, mold spores, bacteria, actinomycetes, and algae were screened for their ability to destroy or transform aflatoxins.

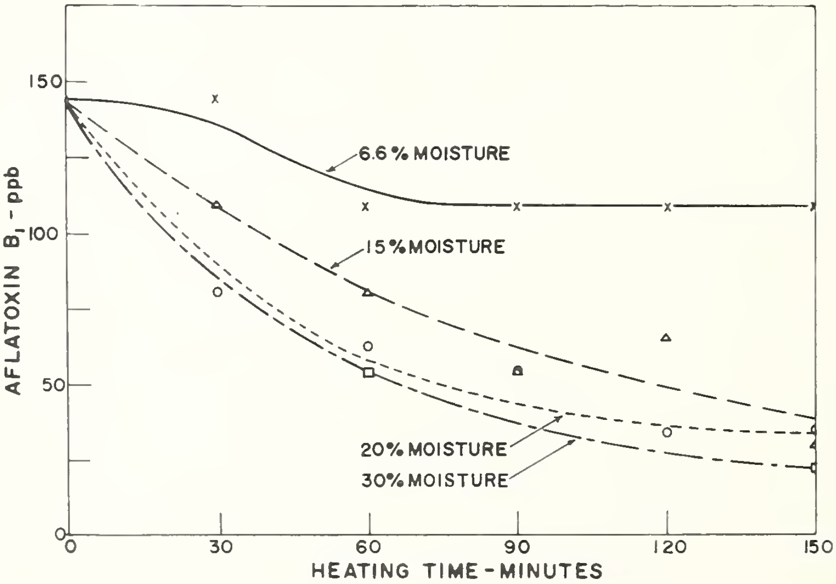


Figure 4. Rate of destruction of aflatoxin B$_1$ in a cottonseed meal at 100° C

Of those organisms tested only one of the bacteria, a flavobacterium, Flavobacterium aurantiacum (MRRL B-184), removed aflatoxin from solution. Aflatoxin-contaminated milk, corn oil, peanut butter, peanuts, and corn were completely detoxified and contaminated soybean was partially detoxified by cells of F. aurantiacum. Duckling assays showed that detoxification of aflatoxin solutions by B-184 was complete. A process for microbiological decontamination of aflatoxin-contaminated edibles has been patented (U.S. Patent No. 3,428,458 (1969)).

A host of chemicals have been screened as reagents for the destruction of aflatoxin. It appears that many chemicals can destroy aflatoxins, but the number that can do so without leaving deleterious residues or without excessive damage to nutrients in foods or feeds appears to be quite small.

One of the more promising chemicals is ammonia, and some of the results with cottonseed and peanut meals are shown in table 2. Shown in the last column, Column F, is a peanut meal. Its aflatoxin content was reduced to barely detectable traces under very mild conditions. The conditions used were 0.25 hour, 15 percent moisture, 163° F., 43 p.s.i.g., and 6.7 percent concentration of ammonia. Some results with cottonseed meal are shown in Column A. This cottonseed meal originally contained 187 p.p.b. total aflatoxins and had 6.6 percent moisture. It was treated with anhydrous ammonia gas at a pressure of 40 p.s.i.g. for one hour at a temperature of 178° F. (81° C.). This treatment appeared to be 100 percent effective in destroying the aflatoxin, as none could be detected in the treated meal.

Table 2. Ammoniation of cottonseed and peanut meals[1]

Meal		A Cottonseed	B Peanut	C Peanut	D Peanut	E Peanut	F Peanut
Aflatoxin B$_1$	(p.p.b.)	144	709	709	709	2,600	64
Aflatoxin, total	(p.p.b.)	187	1,020	1,020	1,020	4,174	110
Reaction conditions:							
NH$_3$ Conc.[2]	(percent)	4.7	3.0	3.0	7.2	6.7	6.7
Meal moist. content	(percent)	6.6	4.0	9.6	14.6	15.0	15.0
Temperature	(° F.)	178	160	150	160	178	163
NH$_3$ pressure	(p.s.i.g.)	40	20	25	40	40	43
Time	(minutes)	60	70	15	60	15	15
Aflatoxin in treated meals:							
Aflatoxin B$_1$	(p.p.b.)	N.D.[3]	203	25	17	17	T[4]
Reduction	(percent)	100	71	96	98	99+	99+
Aflatoxin, total	(p.p.b.)	N.D.[3]	377	39	24	34	T[4]
Reduction	(percent)	100	63	96	98	99+	99+

[1] Anhydrous ammonia.

[2] Theoretical concentration — weight of anhydrous ammonia introduced into reactor per weight of meal treated. Reactor about ¼ filled with meal.

[3] None detected.

[4] Trace detected.

A series of large-scale ammoniations using 2,000- and 2,500-pound batches of cottonseed meals containing about 500 p.p.b. aflatoxin was completed successfully a little over a year ago in cooperation with a private company. The reactor in which this was accomplished was a Schneckens type desolventizer unit, with modification of the ribbon conveyor to provide mixing. Aflatoxin contents of several batches were in the range of 3 to 4 p.p.b. total aflatoxin, and none was detectable in one batch.

Animal feeding studies are currently in progress at the Western Marketing and Nutrition Research Division to evaluate the physiological properties of the ammoniated meals prepared in these tests. These include a 2-year rat-feeding study that was begun in June of 1970. This test is progressing very satisfactorily thus far with no untoward symptoms in the rats fed the ammonia treated meals. A 1-year test with trout, the most sensitive animal species, is planned, and this should begin about May first. These tests are being conducted according to FDA protocol.

So — where do we stand? Unquestionably, prevention of contamination is the best approach, and appropriate preventive measures should be taken at all stages of culture, harvest, transportation, storage, and processing. If prevention has failed, contaminated material may still be salvaged but at a cost, by mechanical removal of contaminated seed, by extraction with polar solvents, or by destruction of aflatoxins with appropriate chemicals. Which procedure is to be preferred in any specific situation depends upon the commodity, the location, the facilities available, the competition, and still other factors. Aflatoxins that may be present in crude oil are effectively removed in conventional refining operations.

References

1. Allcroft, Ruth. 1969. Aflatoxicosis in farm animals. In Aflatoxin — Scientific Background, Control and Implications, pp. 237-264. New York.
2. Ashworth, L. J., Jr., McMeans, J. L., Pyle, J. L., and others. 1968. Aflatoxins in cottonseeds: influence of weathering on toxin content of seeds and on a method for mechanically sorting seed lots. Phytopath. 58: 102-107.
3. Christensen, C. M. 1965. The molds and man. Univ. Minn. Press, 3rd Ed.: 284 + viii pp.
4. Ciegler, A., Lillehoj, E. B., Peterson, R. E., and Hall, H. H. 1966. Microbial detoxification of aflatoxin. Appl. Microbiol. 14: 934-939.
5. Dickens, J. W., and Welty, R. E. 1969. Detecting farmers' stock peanuts containing aflatoxin by examination for visible growth of *Aspergillus flavus.* Mycopathol. Mycol. Appl. 37 (1): 65-69.
6. Dollear, F. G. 1969. Detoxification of aflatoxins in foods and feeds. In Aflatoxin — Scientific Background, Control and Implications, pp. 359-391. New York.
7. ________, Mann, G. E., Codifer, L. P., Jr., and others. 1968. Elimination of aflatoxins from peanut meal. Jour. Amer. Oil Chem. Soc. 45: 862-865.
8. Duggan, R. E. 1970. Controlling aflatoxins. FDA Papers 4 (3): 13-18.
9. Gardner, H. K., Jr., Koltun, S. P., and Vix, H. L. E. 1968. Solvent extraction of aflatoxins from oilseed meals. Jour. Agr. Food Chem. 16: 990-993.
10. Gardner, H. K., Jr., Koltun, S. P., Dollear, F. G., and Rayner, E. T. 1971. Inactivation of aflatoxins in peanut and cottonseed meals by ammoniation. Jour. Amer. Oil Chem. Soc. 48: 70-73.
11. Goldblatt, L. A, (Ed.). 1969. Aflatoxin — Scientific Background, Control and Implications, 472 + xii pp. New York.
12. Mann, G. E., Codifer, L. P., Jr., and Dollear, F. G. 1967. Effect of heat on aflatoxins in oilseed meals. Jour. Agr. Food Chem. 15: 1090-1092.
13. Parker, W. A., and Melnick, D. 1966. Absence of aflatoxin from refined vegetable oils. Jour. Amer. Oil Chem. Soc. 43: 635-638.
14. Pattinson, I., Crowther, P., and Noubey, H. El. 1968. The separation of aflatoxin infected groundnut kernels. Trop. Sci. 10 (4): 212-221.
15. Rayner, E. T., and Dollear, F. G. 1968. Removal of aflatoxins from oilseed meals by extraction with aqueous isopropanol. Jour. Amer. Oil Chem. Soc. 45: 622-624.

AGRICULTURALLY RELATED POLLUTION CONTROL RESEARCH AT THE SOUTHEAST WATER LABORATORY

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ABSTRACT

The Southeast Water Laboratory was completed in 1966 at a cost of $2.3 million. It contains 50,000 sq. ft. of floor space and houses about $2 million worth of special scientific equipment. Its 135 employees provide technical support to further the water quality control efforts of State and local governments in the Southeast and conduct research of national scope in three subject areas: (1) water contaminants characterization, (2) the fate of pollutants in the aquatic environment, and (3) selected agricultural and industrial activities including rural runoff control, phosphate mining, the processing of citrus, poultry, and catfish, production of poultry and catfish, forestry and logging, manufacture of pesticides and fertilizers, and textile manufacturing.

INTRODUCTION

The Southeast Water Laboratory is one of eight laboratories of the old Federal Water Quality Administration now operated by the new Environmental Protection Agency. It was completed in 1966 at a cost of $2.3 million and has about 50,000 sq. ft. of floor space. We have specialized analytical equipment valued at about $2 million, but our greatest asset is a staff of about 135 dedicated employees representing such diverse fields as analytical, organic, electro-, bio- and natural products chemistry; environmental, civil, electrical, mechanical, chemical, and agricultural engineering; limnology; plant physiology; fishery biology; microbiology; soil science; hydrology; computer sciences; administration; and management.

The Laboratory has a dual function; i.e., to provide technical support and training to further the water pollution control efforts of state and local governments within the Southeast and to conduct and monitor research on a national scale in assigned subject areas. The research, accomplished both inhouse and through grants and contracts, is organized into three programs as given below:

(1) National water contaminants characterization research.

During the past decade the need for better methods for detecting and characterizing water contaminants has emerged as one of the major requirements of water-pollution control efforts across the nation. The phenomenon of biological magnification has demonstrated quite dramatically that dilution is not always a suitable means for accomplishing waste disposal. Exotic refractory organic compounds and heavy metals in increasing numbers are proving to be matters of concern in fantastically small quantities.

In response to this need, the Southeast Water Laboratory develops methods for characterizing sources of pollutants, and for chemical analysis at concentration levels sometimes at the parts-per-trillion level. Current effort is concerned with developing analytical methods for new pesticides, better techniques for detecting and tracing oil spills, new techniques for molecular dissolved gases, identification of organics that cause taste and odors, identification methods for non-pesticide organics such as polychlorinated biphenyls and mecurials and the characterization of contaminants that survive the best treatment efforts of kraft pulp mills and textile plants.

One piece of research of particular promise is being done by Rocketdyne Division of North American Rockwell Corporation, under contract cooperatively with the Southeast Water Laboratory. A new instrument, probably the first ever developed specifically for water quality work, is being developed and tested for various applications[1,2,3,4]. Called a pyrographic analyzer, it consists, simply stated, of a pyrolysis chamber for breaking water-borne organic substances into molecular fragments, a chromatographic column for fragment separations, a flame ionization cell for detection, and computerized mathematical interpretation of data output. Whole water is injected into the instrument and the entire subsequent analysis occurs instrumentally.

The mathematical approach is based upon the concept that any type source, such as a municipality, paper mill, or slaughter house, should produce a waste that, when considered as a whole, should have common characteristics or a "fingerprint" that will enable it to be recognized and quantified as a municipal, paper mill, or slaughter house waste discharge, even when combined with other organic wastes in a body of water. If this is true, it will mean that this new instrument and new concept would have application in stream surveys, monitoring, and the enforcement of both water and effluent quality standards. Preliminary data are encouraging.

(2) National pollutants fate research.

This research is increasing our understanding of the physical, chemical, and biological behavior of pollutants that reach surface waters. It is directed toward the development of techniques to describe and predict water quality at any point in a stream. Some aspects of the predictive model being studied include kinetics of significant reactions, the impact of factors such as solar radiation, and the interactions between components of freshwater ecosystems that affect the fate of pollutants.

One approach will simulate a river's physical, chemical, and biological processes in a modeling flume housed in a controlled environment chamber. Construction of this unique facility, called the Aquatic Ecosystem Simulator, is nearing completion and will house a 64-foot artificial stream. Experiments impossible to perform in nature will be conducted under controlled programable conditions of flow, turbulence, air and water temperature, relative humidity, solar and atmospheric radiation, and chemical and biological water quality to determine the fate of residual pollutants. Mathematical models will be constructed and tested for use in establishing water quality criteria, for developing comprehensive plans for water quality control, and for determining waste treatment needs and the type of treatment systems required to meet those needs.

(3) Agricultural and industrial water-pollution control research.

Agriculture and industry in the Southeast are intimately intertwined. This close relationship is reflected in unified research intended primarily to develop and demonstrate the application of new knowledge for the control of recognized sources of water pollution such as phosphate mining, agricultural chemicals manufacturing, poultry and catfish production and processing, processing of citrus products, textile

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[1] Lysyj, Ihor, Instrumental techniques for the identification of pollutants. Publ. in Organic Matter in Natural Waters, Univ. Alaska, College, Alaska, 1970.

[2] Lysyj, Ihor. Pyrographic gross characterization and monitoring of water pollutants. Publ. in Proc. Natl. Sympos. Data and Instrumentation for Water Quality Management. Univ. Wisconsin Press, 1970, pp. 145-159.

[3] Lysyj, Ihor, Nelson, K. H., and Webb, S. R. Analysis of multicomponent organic mixtures in aqueous media by pyrolysis. Water Res. 4: 151-163, 1970.

[4] Lysyj, Ihor, Newton, P. R., and Taylor, W. J. Instrumental-computer system for the analysis of multicomponent organic mixtures. Submitted for publication in Analytical Chemistry.

manufacturing, forestry and logging, and agricultural runoff. The significance of each pollution source is being assessed and the adequacy of existing technology to control such sources is being evaluated. Pilot or full-scale demonstration projects are funded when new knowledge may be demonstrated or gained.

Your program chairman has requested that I describe in some detail our work on water pollution caused by agricultural use of pesticides, and on problems related to textile manufacturing and citrus processing.

(4) Agricultural-runoff control.

Agricultural-runoff-derived pollution, as we define it, may include agricultural chemicals (pesticides and fertilizers), sediments, animal and crop wastes with their associated pathogens, and air-pollution fallout. The study of pesticide runoff is one of our major inhouse research activities, having its genesis in 1959 in Atlanta, Ga., as the Pesticide Pollution Control Project.

The original purpose of that project was to prove or disprove the concept that washoff of perticides from the soil was a source of significant water pollution, and if so, to evaluate the problem. Prior to 1959, the runoff of these chemicals had been demonstrated only circumstantially; their occurrence and seasonal distribution had not been quantified. Field investigations carried on between 1959 and 1964 in South Carolina, Alabama, and Louisiana established that pesticides associated with runoff indeed do pollute water. Moreover, the contribution from land could be continuous throughout the year at levels in water less than 1 microgram per liter (1 p.p.b.) from areas of heavy usage of persistent pesticides. Other pesticides, less persistent or less heavily applied, were found to pollute seasonally or not at all. Some pesticides are transported from land to stream in solution in runoff water. Others were found to have marked affinity for soil particles, reaching the water absorbed on sediment or organic matter. Acutely toxic pollution levels were found to occur locally, sporadically, and associated with heavy rainfall, accidents, or carelessness. The significance of pesticide pollution is not adequately expressed by the small quantities found in water because of the tendency of some compounds to concentrate in living organisms and in biologically active substrates. The methodology and approaches developed in this phase of the research program have been widely used to further extend knowledge of the problem.

Although the extent and nature of the pesticide pollution problem became reasonably well established, no measures were evident that could be depended upon to prevent pesticide runoff. It was reasoned that if we knew more about those processes that determine fate and behavior of pesticides in soils, we could establish conditions under which pollution would occur. Control then could be achieved by suitable preventive usage recommendations, engineering, and management techniques. With that goal in mind, a shift in project emphasis was made from the field to the laboratory to seek answers to fundamental questions. Laboratory research for the past six years has been directed toward those ends and has resulted in the development of a mathematical model to predict pesticide runoff from agricultural lands. Negotiations are underway with the Southern Piedmont Soil and Water Conservation Research Laboratory, ARS, USDA, for cooperative field-testing of the model in the summer of 1971.

(5) Textile manufacturing.

The textile industry, in 1964, used 148 billion gallons of water and discharged 91 percent of it as waste effluent. Only 35 billion gallons received waste treatment of any kind. The industry is complex, variable, and in constant transition. Those segments producing major amounts of liquid wastes are the scourers and finishers of wool, and the cotton and synthetic fiber finishers[5].

In the wool industry, scouring removes impurities approximately equal in weight to the residual fiber weight, creating one of the strongest liquid wastes, in terms of biological oxygen demand (BOD) of any industry. Wool grease presents an especially difficult treatment problem. Cotton finishing wastes, although not nearly as strong as those produced by the wool industry, are characterized by high BOD and frequently high color. Synthetic-fiber-finishing wastes generally are less important BOD sources and can be significantly different because of the toxicity of dye wastes when metallic ion containing carriers are used. Data on average waste characteristics, gross load produced, and net waste load discharged after treatment are given in tables 1, 2, and 3.

Wastes from textile mills are of two types, based on source: (1) The natural impurities inherent in the fiber, such as grease, dirt, vegetable waxes, and suint; and (2) the process chemicals used, such as detergents, dyes, sizes, oils, and lubricants.

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[5] Industrial Waste Profile: Textile Mill Products. USDI, Federal Water Pollution Control Adm. IWP #4, 1967.

Table 1. Average waste characteristics per 1000 lb. finished fabric (1963)[1]

Fiber	Water	BOD	Suspended solids	Total dissolved solids
	1,000 gal.	Lb.	Lb.	Lb.
Wool	30 to 70	296	- - -	- - -
Cotton	30 to 70	155	70	205
Synthetics	3 to 29	20 to 250	20 to 160	20 to 600

[1] From Industrial Waste Profile: Textile Mill products. U. S. Department of the Interior, Federal Water Pollution Control Administration. I.W.P. #4, 1967.

Table 2. Gross wasteload produced (1963)[1]

Fiber	Fiber consumed	Volume	BOD	Suspended solids	Total dissolved solids
	Million lb.	Billion gal.	Million lb.	Million lb.	Million lb.
Wool	412	26.0	132	[2]310	- - -
Cotton	2,015	97.6	528	166	498
Synthetics	975	17.2	177	178	358

[1] From Industrial Waste Profile: Textile Mill Products. U. S. Department of the Interior, Federal Water Pollution Control Administration. I.W.P. #4, 1967

[2] Grease.

Table 3. Net wasteload discharged (1963)[1]

Fiber	Liquid wastes produced	Liquid wastes treated[2]	BOD	Suspended solids	Total dissolved solids
	Billion gal.	Billion gal.	Million lb.	Million lb.	Million lb.
Wool	26.0	15.5	70	- - -	- - -
Cotton	97.6	48.8	309	97	423
Synthetics	17.2	- - -	96	71	322

[1] From Industrial Waste Profile: Textile Mill Products. U. S. Department of the Interior, Federal Water Pollution Control Administration. I.W.P. #4, 1967.

[2] Treated by industry or discharged to sewers for treatment at municipally owned plants.

Our water-pollution control philosophy for the textile-manufacturing industry, as with other pollution sources, has been largely oriented toward BOD reduction, although attention has been directed toward controlling other traditional water-quality parameters such as pH, temperature, color, and suspended and dissolved solids. By and large, treatment is accomplished biologically through use of activated sludge or trickling filter systems, by variation of these systems, or by lagooning.

Current thought is directed toward achieving the ideal of no waste production. While this may be a somewhat Utopian goal, there is little question that we can do more byproduct recovery. There is also an open field for the development of chemical waste treatment processes in lieu of or supplemental to biological treatment systems.

One of our major concerns is to know more about the removal of dye wastes. Currently, if these wastes are decolorized or diluted to the degree that they are no longer evident, it is commonly assumed that no problem exists. Our long-standing interest at the Southeast Water Laboratory in the fate and effects of trace-chemical contaminants leaves us dissatisfied. We know that there are about 5,000 proprietary dye compounds on the market composed of single or, more commonly, mixtures of pigments. Only the general chemical nature of these dyes is known by the users. Development of methods to treat and remove them is made difficult by the intermittent use of dyes. It is common to drive by a mill in the forenoon and to see the stream into which its wastes discharge flowing along reddish in color, while it may be blue in the afternoon.

Currently, textile manufacturing wastewater quality control research at the Southeast Water Laboratory is largely a grants management program, but a strong inhouse research capability will be developed as rapidly as budgets and personnel authorization will permit. Demonstration grants, active or pending, include a system for wastewater reclamation and use, a plan for reduction of copper and ammonia in wastewater, a study of the photochemical degradation of commercial dyes, a system for recovery of desizing wastes, the treatment of cotton textile waste by enzymes in a unique high rate trickling filter, a survey of the state-of-the-art of textile waste treatment, a study of gamma-radiation-induced oxidation of textile effluents, precipitation of zinc and its recovery, and the reuse of plant effluent and cooling water blowdown as process water. The combined value of grants now funded is about $1.3 million.

Citrus processing.

The citrus processing industry in the United States is located primarily in Florida, but it is also significant in California and in Texas. Florida produces about 75 percent of our oranges and 80 percent of our grapefruit. Approximately 50 percent of the oranges and 80 percent of the grapefruit are processed for sale other than as whole fruit. Fifty-two processing plants in Florida in 1965 discharged 130 MGD of wastewater having a BOD of 319,000 lb.[6]. Most of Florida's citrus fruit is processed to single-strength or concentrated juice, yielding byproducts including 350,000 tons of dried pulp and 40,000 tons of citrus molasses[7] in 1965-66, as well as smaller amounts of peel oil, flavonoids, seed oil, meal and hulls, pectin substances, and various fermentation products[8].

Fresh-fruit-packing liquid wastes contain dirt, debris, a small amount of detergent, and perhaps color additive and wax, and have a BOD of about 200 mg./1. Processed fruit wastes are stronger. Sectioning wastes have a BOD of 700 to 1,000 mg./1 and may contain lye, particularly in grapefruit sectioning. Single strength juice wastes have a BOD of 300 to 500 mg./1; concentrate wastes, 400 to 600 mg./1. Cooling water used in the barometric condenser may have a BOD of 30 to 50 mg./1 and a temperature of 105°F. Byproducts manufacturing also produces wastes. If peel oil is recovered by centrifugation for use as a flavoring, the effluent from the centrifuge may have a BOD of 100,000 mg./1[9].

Concentrated citrus oils present in peel press liquor and in wastes from peel oil recovery are not amenable to conventional biological treatment. When slugs of these wastes are dumped (through carelessness or ignorance) into an aerated treatment unit, an almost unbreakable foam develops and solids become bulky and difficult to settle. Treatment efficiency is further reduced because citrus oils are toxic to treatment microorganisms. Peel press liquor is commonly concentrated through evaporators to form citrus molasses, a byproduct which is added to citrus pulp for cattle feed. When the evaporators become overloaded, these wastes should be trucked to suitable dump areas for land disposal.

Spray irrigation is sometimes used for liquid waste disposal where land is suitable for infiltration and percolation. Efforts to grow crops (including orange trees) under spray irrigation with citrus wastes have failed, presumably because of the presence of toxic compounds and variable pH. The waste stream may be acidic because of citric acids or basic because of the presence of alkaline cleaning and processing solution residue.

Aerated lagoons are often favored for citrus waste treatment because long retention times make them somewhat tolerant of shock loads and operating mistakes. Unfortunately, they require large areas of land, which is often expensive.

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[6] First Yearly Report, Research and Development Grant WPRD-161-01-(R2)- 62 of USDI, Federal Water Pollution Control Adm. Prepared by Environmental Engineering, Inc., Gainesville, Fla.

[7] Treatment of Citrus Processing Wastes. Report of Grant WPRD-38-01-67 from USDI, Federal Water Quality Adm. to the Coca-Cola Co., Foods Division, Orlando, Fla. Prepared by Black, Crow, and Eidsness, Inc., Gainesville, Fla., 1970.

[8] Hendrickson, R., and Kesterson, J. W. By-products of Florida Citrus. Bull. 698, Univ. Fla., Agr. Expt. Sta., Gainesville, 1965.

[9] Dause, J. L., Hill, D. W., and Sargent, T. N. Citrus Waste Treatment Research Needs, Internal Document of Southeast Water Laboratory (not published or available).

Combining citrus wastes with municipal sewage provides a three-fold advantage. The sewage provides a source of nutrients needed for biodegradation of the nutrient-poor citrus wastes and seed microorganisms for biological waste treatment, and it improves the settling characteristics of light solids formed from the fruit processing wastewater treatment. It is important to note that these advantages do not eliminate problems caused by shock loading.

Two full-scale waste treatment plants have been successful, using the extended-aeration modification of the activated sludge process on a demonstration basis. In one case, joint treatment with municipal wastes provided needed nutrients; in the second, anhydrous ammonia and phosphoric acid were added in carefully controlled amounts for necessary nutrients.

Low BOD cooling water from barometric and other condensers is commonly discharged untreated. One plant has successfully recycled processing wastewater through its barometric condenser prior to discharge. Combining discharged cooling water with other wastes before treatment has been attempted, but the resulting treatment is inefficient due to the dilute strength of the wastewater and in the increased size of treatment facilities needed for the added volume of wastewater.

Design parameters are being developed for plants to treat citrus processing wastewaters. Also needed are additional ways of processing or disposing of peel press liquor and other concentrated wastes. Special fermentation processes have been suggested to produce byproducts without requiring an evaporator. Efforts are needed to provide a complete recycle system where wastewater is treated sufficiently for reuse throughout the citrus plant. Several demonstration grants in Florida have been funded having a total value of about $0.6 million.

Research and demonstration grants.

Funds are available for research and demonstration grants from the Water Quality Office of the Environmental Protection Agency on agricultural waste disposal problems. More specific information relative to classes of grants, eligibility, and grant limitations is contained in an appended statement. Grant applications may be obtained from the Southeast Water Laboratory or from the Environmental Protection Agency, Southeast Regional Office, Suite 300, 1421 Peachtree St., N.E., Atlanta, Ga. 30309. We invite your participation as we have many interests in common.

APPENDIX

Research and demonstration grants

Applications for grants may be submitted to the Water Quality Office of the Environmental Protection Agency for the following classes of projects, to accomplish the purposes indicated:

Class I. — Those projects intended and designed to establish, discover, develop, elucidate, or confirm information on the causes, control, and prevention of water pollution.

Class II. — Those projects intended to demonstrate the applicability and utility of research findings on the causes, control, and prevention of water pollution.

Class III. — Those projects that will assist in the development of, and/or will demonstrate, a new or improved method of controlling the discharge into any waters of untreated or inadequately treated sewage or other wastes from sewers that carry storm water, both storm water and sewage, or other wastes.

Class IV. — Those projects that will assist in the development of, and/or will demonstrate, advanced waste treatment and water purification methods (including the temporary use of new or improved chemical additives that provide substantial or immediate improvement to existing treatment processes) or new or improved methods of joint treatment systems for municipal and industrial wastes.

Eligibility. All persons found by the Commissioner to be qualified by scientific or other relevant competence to carry out a proposed project in accordance with these regulations, and otherwise qualified, shall be eligible for a grant award, except that grants for Class III and Class IV projects can be made only to a State, municipality, or intermunicipal or interstate agency.

Grant limitations. (a) Grants for Class I and Class II projects shall be subject to the following limitation: that no grant shall be made in an amount exceeding 95 percent of the estimated total eligible cost of the project as determined by the Commissioner.

(b) Grants for Class III and Class IV projects shall be subject to the following limitations:

(1) No grant shall be made unless the project shall have been approved by the appropriate State water pollution control agency or agencies;

(2) No grant shall be made for more than 75 percent of the estimated total eligible cost of the project as determined by the Commissioner; and

(3) No grant shall be made for any project unless the Commissioner determines that such project will serve the purpose set forth in Section 6(a) of the Act.

(c) Grants for Class V projects shall be subject to the following limitations:

(1) No grant shall be made in excess of $1 million for a project;

(2) No grant shall be made for more than 70 percent of the estimated eligible cost of the project as determined by the Commissioner; and

(3) No grant shall be made for a project unless the Commissioner determines that such project will serve a useful purpose in the development or demonstration of a new or improved method of treating industrial wastes or otherwise preventing pollution of waters by industry and that the method shall have industrywide application.

SESSION II: POLLUTION-ABATEMENT RESEARCH IN THE STATES

H. Rouse Caffey, Agricultural Experiment Station,
Baton Rouge, La., Chairman

AGRICULTURAL PESTICIDE RESIDUES

by

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(No copy of this paper available for publication.)

AGRICULTURAL POLLUTION OF WATER INPUT — STORAGE — OUTPUT OF PLANT NUTRIENTS IN A MULTI-IMPOUNDMENT SYSTEM ON A LARGE RIVER[1]

by

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INTRODUCTION

All water that contributes to the surface runoff in a river basin is the solvent and vehicle for transporting varying amounts of more than 15 elements that are essential nutrients for aquatic plant and animal growth. The concentrations of these elements in runoff waters and eventually in river waters are dependent upon the types of soils and agricultural operations that occur in the drainage area, plus the amounts of domestic sewage and industrial effluents that may also be discharged within this area. Thus, a heterogenous mixture of varying amounts of plant nutrients comprise the input waters to a mainstream impoundment.

Within the impoundment a multitude of events may occur that determine the fate of input nutrients. A portion of the nutrient content of an impoundment is always present in soluble form. Some of these soluble nutrients originate from resolution from bottom muds and from waste and decomposition of plants and animals. A portion of the nutrients may be precipitated as colloidial matter directly into the bottom muds, which may be a temporary or permanent type of storage. Another portion of the input nutrients may be utilized in the growth and reproduction of bacteria, fungi, algae, or rooted aquatic plants, which in turn may be consumed by some animal form, or the plants may die and their nutrients be deposited in the muds. The animal population will eliminate most of the nutrients it consumes as waste and retain only a small portion in its growth. The growth retained portion of nutrients may be removed from the environment if the animal flies, walks, crawls, or is bodily removed from the impoundment. If the animal remains in the impoundment, it eventually dies, and the nutrients may return to the bottom muds, or become a food item for another animal and the waste then returns to the bottom muds. Finally a portion of the input nutrients pass out of the impoundment into the tailwaters, where they are then classified as outlet nutrients.

These outlet nutrients may occur as soluble forms, bacteria, fungi, algae, occasionally rooted plants, various animal forms, and organic materials and soil colloids. All forms of these nutrients move downstream to combine with additional drainage area runoff and eventually become the input nutrients for the next impoundment, where the retention-storage process is again repeated, and so on until the river flows into the ocean.

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[1] This research was jointly supported by Auburn University Agricultural Experiment Station and Water Resources Research Institute and by United States Department of Interior Office of Water Resources Research.

What has been described above might well be called an abbreviated nutrient cycle for an impoundment. To best utilize this cycle to man's advantage required a knowledge of the quantity of each nutrient involved in each of the niches described for the environment, as well as the rates of partial and permanent retention or storage. With such information available, it would be possible to determine the element or elements responsible for overproduction of noxious plants and to isolate and eventually correct the source(s).

Since the nutrient cycle of impoundments is intimately related to eutrophication, and since a moderate degree of eutrophication is essential for fish production in river impoundments, a tolerable nutrient loading is beneficial. In those areas where there are excessive nutrients, seasonal aquatic plants are possible retention sites for excess nutrients during periods of hot weather and low stream flow, and then cold weather and frost provides a mechanism for their slow release when there is a higher rate of stream flow.

Location of Study Area

The 3 mainstream impoundments that were studied are located on the Chattahoochee river between West Point, Ga., and Chattahoochee, Fla., and the Flint river between Bainbridge, Ga., and Chattahoochee, Fla. (figure 1).

The Chattahoochee river rises in the Blue Ridge foothills of nothern Georgia. The uppermost impoundment is Lake Sidney Lanier, which has a surface area of 38,000 acres and a drainage area of 1,040 square miles. The next major impoundment, Barlett's Ferry Reservoir, is approximately 150 miles downstram. It has a surface of 5,850 acres and a drainage area of 4,260 square miles. This is the upstream reservoir of the 3 impoundments included in this study.

Immediately above Barlett's Ferry Reservoir, the U. S. Army Corps of Engineers is currently constructing a dam that will produce another 20,000-acre inpoundment on the Chattahoochee river. This dam is scheduled for completion in 1972.

Lake Eufaula (Walter F. George Reservoir) is the 10th downstream impoundment on the Chattahoochee river, with a surface area of 45,000 acres, an average depth of 20.4 feet, and drainage area of 7,460 square miles. The average rate of flow since its impoundment in 1963 has been 10,800 c. f. s.

Dispersed throughout this upper Chattahoochee drainage area are numerous cities and towns that discharge both domestic and industrial wastes in varying degrees of stabilization into the water. By the time the river reaches the upper end of Bartlett's Ferry Reservoir it has received the effluent from over 1/2 million people, and by the time it reaches the upper end of Lake Eufaula it has received the effluent of 3/4 million people and their associated industrial wastes. Agricultural wastes in this portion of the drainage area are believed to be negligible, since less than 30 percent of these lands are in cultivation and pastures.

Approximately 40 miles downstream from Columbus Ga., a paper mill with a 1,600-ton-per-day capacity, began discharging its treated effluent, not to exceed 4,200 pounds of BOD per day, into Lake Eufaula in 1967. This mill waste is released 40 feet below the water surface, at a point on the reservoir which coincides with the uppermost area where oxygen depletion in deeper water was detected in both 1965 and 1966 but did not occur this far upstream in 1967, 1968, or 1969.

Approximately 10 miles downstream from this paper mill installation on Lake Eufaula, runoff wastes from a swine production operation, whose pastures include an area in excess of 1,000 acres, enter the impoundment via two small streams.

Lake Seminole (Jim Woodruff Reservoir) which is formed by a dam at the mouths of the Chattahoochee and Flint rivers, is the 12th impoundment on the Chattahoochee and the 3rd impoundment on the Flint. This reservoir has a surface area of 37,500 acres, an average depth of 9.8 feet, and a combined drainage area of 17,150 square miles (8,650 square miles on the Chattahoochee arm and 3,500 square miles on the Flint arm). This area was inundated in 1957.

Incoming waters into Lake Seminole were more varied in chemical composition than were those entering Lake Eufaula. The Chattahoochee waters are very soft (15 to 18 p.p.m. $CaCO_3$ equivalent), the Flint waters are soft (45 to 55 p.p.m. $CaCO_3$ equivalent). These latter waters are discharged from large limestone springs originating in an area of lime sinks.

Another paper mill with a capacity in excess of 3,000 tons per day is located on the Chattahoochee river approximately 7 miles below Columbia Dam. This mill releases 17,250 pounds of BOD per day of partially stabilized waste into the river. A depression in D. O. content of water has been observed for 25+ miles downstream from this release point.

On the Flint arm, the City of Bainbridge,

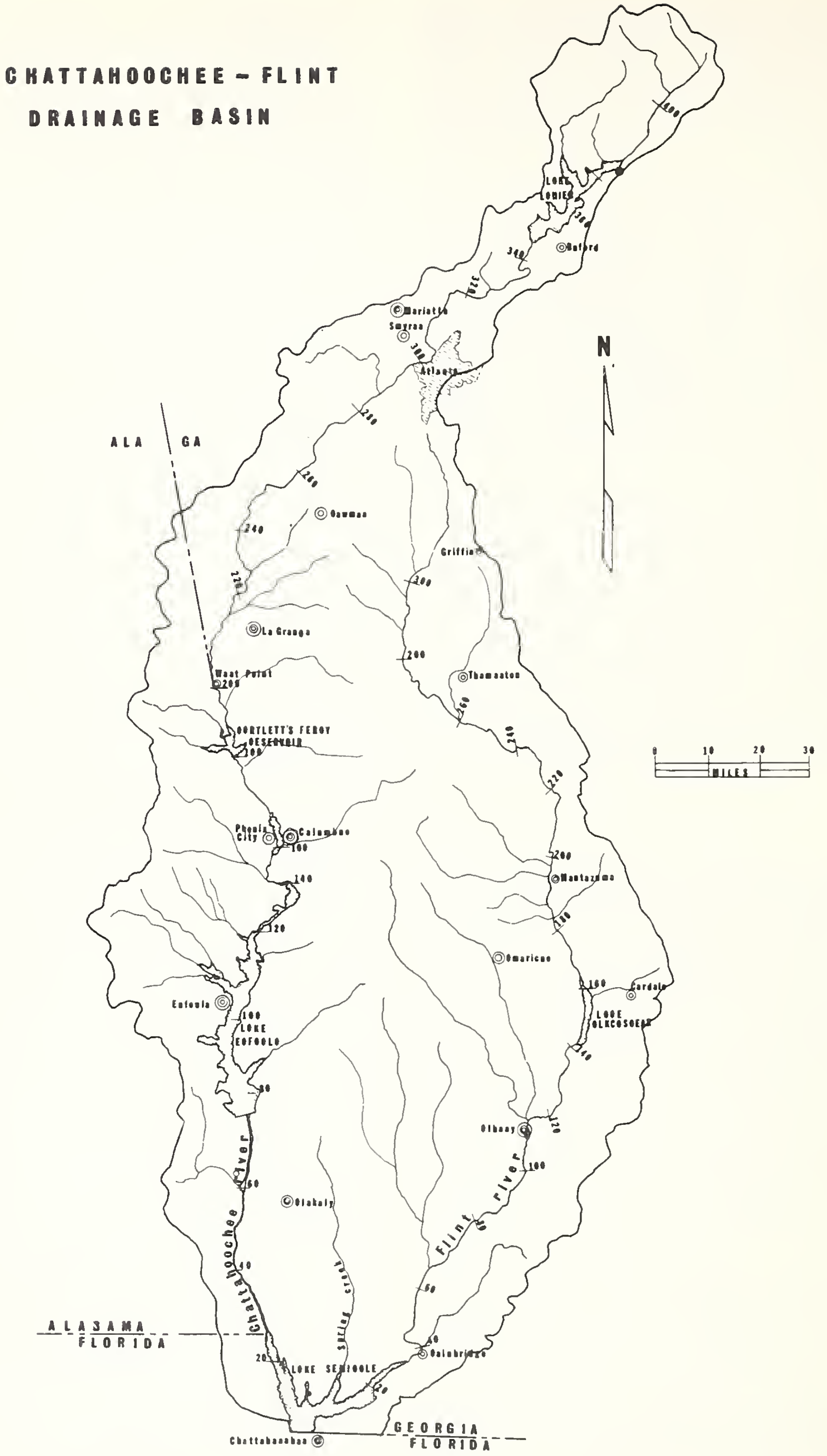

Figure 1. Map of Chattahoochee and Flint rivers drainage basin

Ga. released untreated domestic sewage into the upper end of Lake Seminole.

As a result of its large areas of shallow water, excessive nutrient loading, and swamplike lake bottom, Lake Seminole has supported a population of aquatic weeds consisting of as great a number of different species as can be found in any other impoundment in the United States. Many species were present in sufficient quantities to permit a reliable estimate of their nutrient retention-storage-release potential in an impoundment situation.

Data Collection Technique

Detailed data on sampling water, suspended matter, hydrosol, plants, and fish, and the analytical techniques for determining the concentrations of N, P, K, C, Ca, Mg, Na, Fe, Mn, Cu, Zn, Cr, Cd, Ni, Pb, Mo, Co, and Sr in such samples have been described by Lawrence (1968)[2].

Samples of water and suspended matter (mainly phytoplankton) were collected at intervals throughout the study period. Chemical analyses of the nutrients included in this study were made on both filtered water and suspended matter.

Hydrosol sampling was carried out by a special technique that was developed by Lawrence[3] and the nutrient data are expressed as pounds per acre per 0.01 inch of depth.

Sampling of rooted aquatic plant populations was carried out in such a manner as to obtain estimates of the wet and dry weights per acre of each major species that occurred within the study area. Samples of each of these dried plant species were analyzed in the laboratory for their nutrient composition.

Fish population estimates were obtained by rotenone sampling of given areas in the impoundments. Chemical analyses of dried samples of the various fish species were made in the laboratory to determine their elemental composition.

Runoff data on the Cahttahoochee and Flint rivers were furnished by the U. S. Army Corps of Engineers and by the U. S. Geological Survey.

Results and Discussion

The intent of this paper is to present data on the input-assimilation and retention-output of the inorganic nutrients, N and P, in a multi-impoundment system on a large river, and to attempt to ascribe the sources of these nutrients within each area being investigated. Only the April through October 1968 and 1969 data on N and P will be utilized in describing the sequence of events that occurred throughout the impoundment system.

The soluble nutrient supply included only those fractions of the 2 elements that were detectable in the water after it had passed through an 0.8-micron Millipore filter. The suspended matter was that material present in raw waters that was retained upon the 0.8 micron Millipore filter.

Nutrient input for each impoundment was estimated from the average concentrations of each element in its soluble form and in the suspended matter of the inflowing waters. In Barlett's Ferry Reservoir, the total inflow included the quantity contributed by the Chattahoochee River and by the Osanippa and Halawakee Creeks. Output was determined by the release through Barlett's Ferry Dam. The estimates of inflow waters in Lake Eufaula were more difficult, since the total flow increased 50 percent from the upper end of the lake to the dam. To compensate for this increase, the lake was divided into an upper region, middle region, and lower region, as indicated in figure 2. The output flow was that quantity of water passing through Walter F. George Lock and Dam. The input flow for Lake Seminole was also complicated and had to be calculated for the Chattahoochee arm, the Flint arm, and the Spring Creek arm, as shown in figure 3. The output data were determined by that quantity of water that passed the Jim Woodruff Lock and Dam during the study periods.

The assimilation data include those quantities of nutrient that are included in the fish and rooted plant population in each impoundment.

The retention data may include the differences between input quantities of nutrients, providing the output is less than the input plus assimilation quantities. The hydrosol data are also included as retention data. These hydrosol data represent the total N content and that portion of P content that could be extracted with aqua regia.

Information on surface area, drainage area, average depth, water volume, and flow data (from April 1 through October 31, 1968 and 1969) for each impoundment are given in table 1.

Tubular summaries for N data on water and

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[2] Lawrence, J. M. Dynamics of chemical and physical characteristics of water, bottom muds, and aquatic life in a large impoundment on a river. Auburn Univ. Agr. Expt. Sta. Zoo-Ent. Dept. Ser. Fisheries No. 6. 1960.

[3] Lawrence, J. M. Dynamics of chemical and physical characteristics of water, bottom muds, and aquatic life in a large impoundment on a river, Phase II. Auburn Univ., Agr. Expt. Sta. (In press).

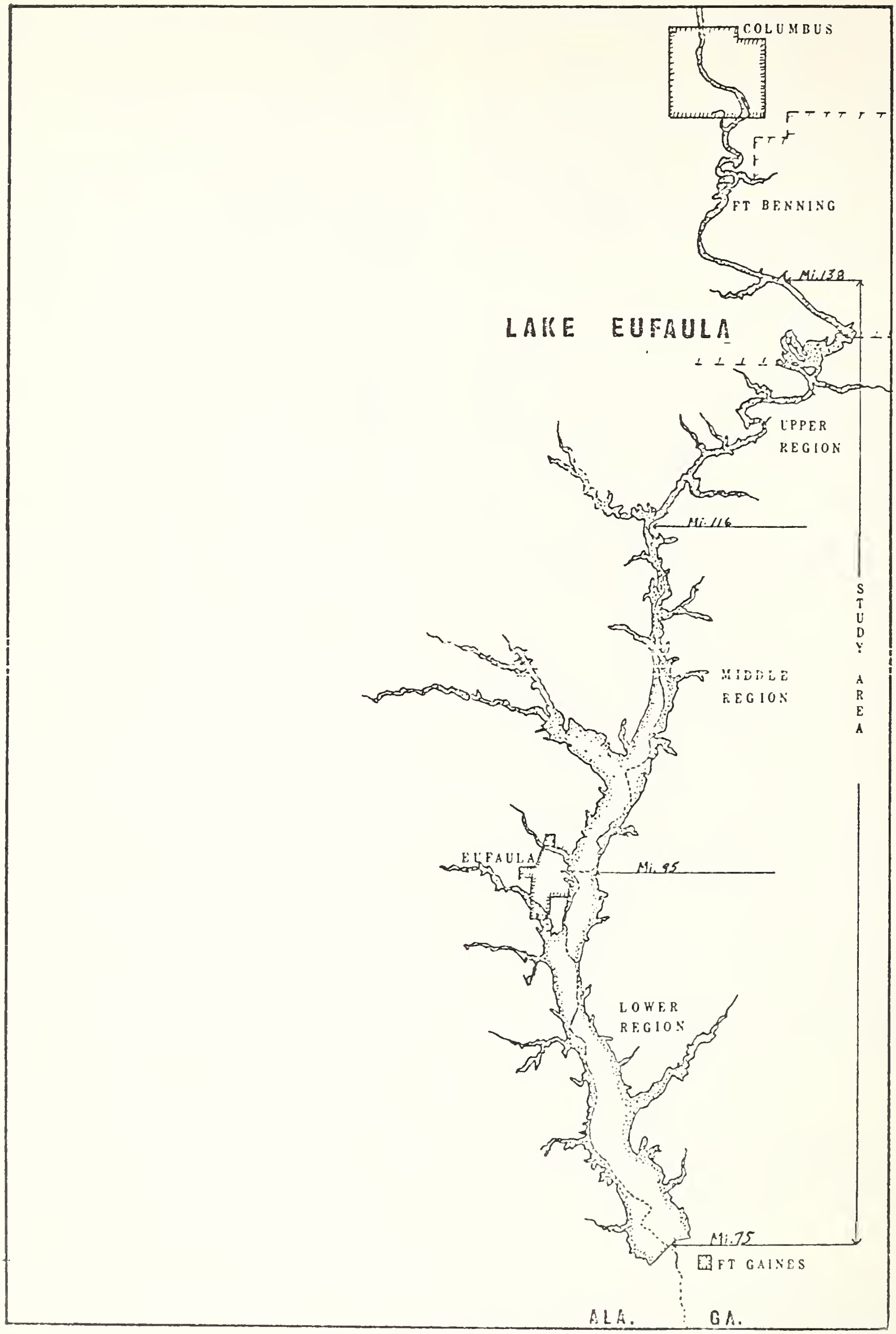

Figure 2. Study areas on Lake Eufaula

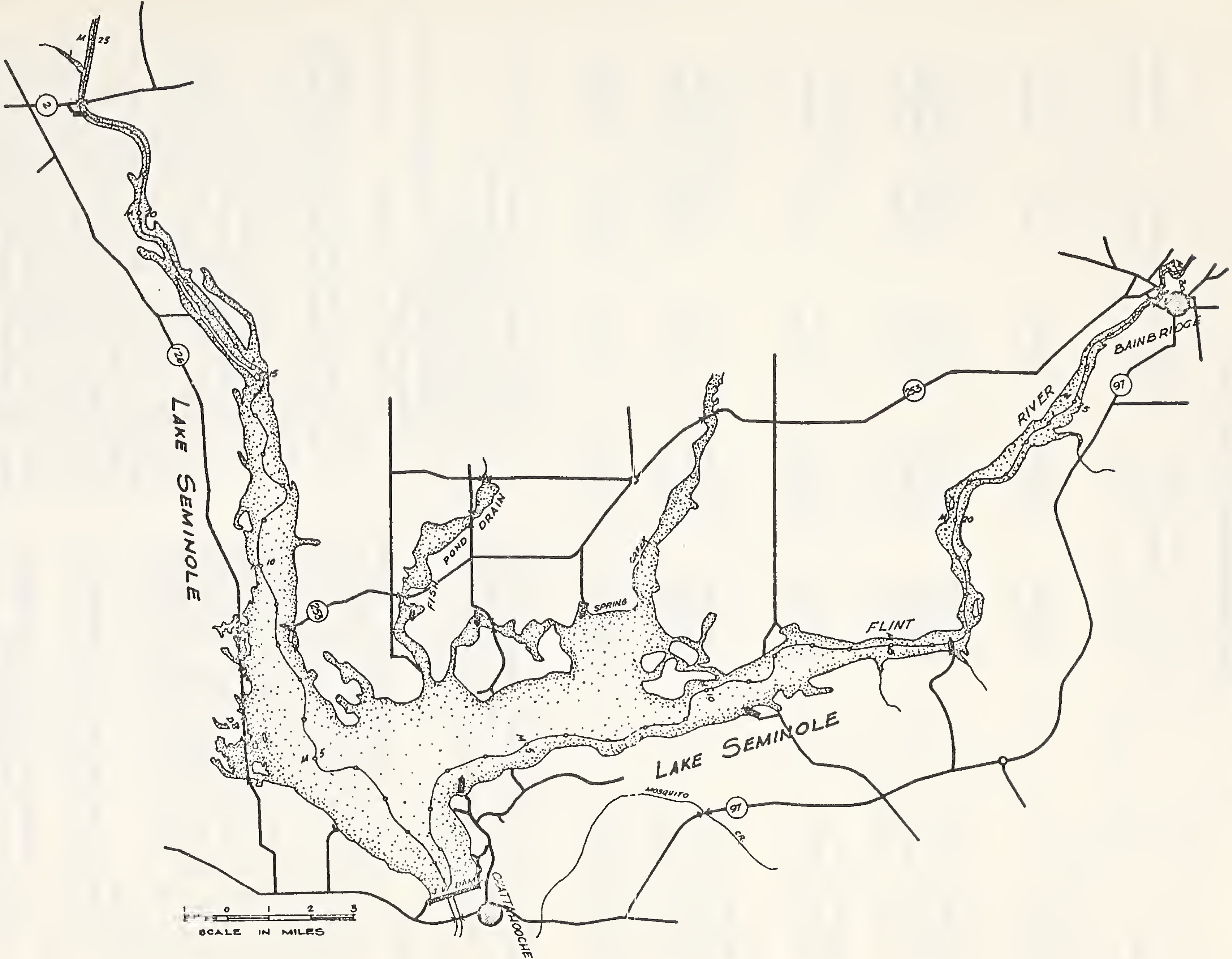

Figure 3. Study areas on Lake Seminole

Table 1. Pertinent information on total flow, total drainage area, total surface area, and total volume of Bartlett's Ferry Reservoir, and Lakes Eufaula and Seminole for periods April through October, 1968 and 1969

Location	April-October flow (Acre-feet) 1968	1969	Drainage area (Miles^2)	Surface area (Acres)	Total volume (Acre-feet)
Chattahoochee River:					
Bartlett's Ferry					
Upper end	1,275,500	1,310,000	4,000	5,850	146,250
Dam	1,413,536	1,452,000	4,260		
Lake Eufaula:					
Ft. Benning bridge	1,614,567	2,054,000	5,000	6,656	166,400
Cottonton	1,787,298	2,241,000	5,535	14,130	282,600
Eufaula bridge	2,150,828	2,696,000	6,660	23,885	477,700
Walter F. George Dam	2,409,083	3,020,000	7,460		
Lake Seminole:					
Columbia Dam	3,845,153	3,949,000	8,340	13,500	126,900
River Mile 3	3,965,026	4,072,000	8,600		
Flint River:					
Lake Seminole:					
Bainbridge bridge	2,350,905	2,414,000	7,500	14,500	136,300
River Mile 3	2,490,366	2,557,000	7,750	7,500	70,500
Spring creek mouth	237,510	244,000	850		
Apalachicola River:					
Jim Woodruff Dam	6,692,902	6,874,000	17,200	35,500	333,700

hydrosol in the 3 impoundments are given in tables 2 and 3, and for P data in tables 3 and 4.

The organization of the tabular summary for each element in each impoundment for 1968 and 1969 was as follows:

Water:

Average total concentration of an element in raw water was expressed as p.p.m. (For 1968, only the NH_3 content was determined. In 1969, the NH_3, NO_2, and NO_3 content of H_2O and total N of suspended matter were determined.) Standing crop was the averaged quantity of an element in pounds per acre for the period April through October. Total quantity was pounds of an element per square mile of drainage area that passed a given point in study periods.

Hydrosol:

Total pounds per acre of an element in a 0.01-inch layer of hydrosol.

Fish:

Total standing crop of fish, expressed as pounds per acre on wet-weight basis.

Averaged concentration of an element in fish population, expressed as percent on dry-weight basis.

Total pounds of an element contained in the standing crop of fish per acre.

Aquatic Plants (rooted):

Species identification.

Numbers of acres of a species present in each impoundment.

Net weight of a species in pounds per acre.

Averaged concentration of an element in a species, expressed as percent of this species' dry weight.

Total quantity of an element in a species, expressed as pounds per acre.

It is immediately obvious from an examination of these data on both N and P, that extreme variation in total quantities of each element existed in these river systems in relation to time and to location. As an aid in studying these data, a profile of the Chattahoochee River is given in figure 4, and of the Flint River in figure 5.

It might be assumed that the high quantity of N and P passing through Bartlett's Ferry Reservoir was due primarily to domestic sewage, since the sewered population above this input was approximately 600,000. However, 500,000 of these people dispose of their wastes into the

Table 2. Averaged concentration of N in water (p.p.m.), averaged standing crop of N in impounded waters (lb./acre), and total N passing a given point from April through October (lb./mi.^{2} of drainage area) in 1968 and 1969

Location	Average concentration N in water (p.p.m.) 1968[1]	1969	Standing crop N (lb./acre) 1968[1]	1969	Total N, April-October (Lb./mile^2 drainage area) 1968[1]	1969
Chattahoochee River:						
Bartlett's Ferry Reservoir:						
Input	0.266	0.780	19.6	68.0	230	827
Output	.314	.994			282	925
Lake Eufaula:						
Ft. Benning bridge	.205	.687	12.75	47.0	178	771
Cottonton bridge	.173	.511	9.60	33.0	152	565
Eufaula bridge	.181	.472	10.10	23.0	158	522
Walter F. George Dam . . .	.194	.388			168	429
Lake Seminole:						
Columbia Dam	.180	.239	5.03	9.4	226	309
River Mile 3	.216	.293			267	379
Flint river:						
Lake Seminole:						
Bainbridge bridge	.186	.395	5.03	9.26	157	347
River Mile 3	.212	.327	3.95	4.72	183	295
Spring creek mouth	.154	.184	5.45	3.65	117	145
Jim Woodruff Dam	.216	.174			226	190

[1] 1968 data does not include values for N content of suspended matter. Also, soluble N data for 1968 includes NH_3 form only.

Table 3. Estimated total pounds per acre of N and P in a 0.01 inch layer of hydrosol for various portions of reservoirs in 1968 and 1969

Location	Total lbs/acre in 0.01 inch layer hydrosol N 1968	N 1969	P 1968	P 1969
Chattahoochee River:				
Bartlett's Ferry Reservoir	7.83	6.03	7.3	11.2
Lake Eufaula:				
Upper region	5.77	6.67	7.1	8.1
Middle region	8.60	8.60	5.6	11.3
Lower region	6.50	10.00	2.5	9.5
Lake Seminole:				
Chattahoochee river arm	8.6	8.3	- - -	2.7
Flint River:				
Lake Seminole:				
Flint river arm	7.0	5.8	1.1	6.1
Spring creek arm	8.7	0.7	1.3	0.7

Table 4. Averaged concentration of P in water (p.p.m.), averaged standing crop of P in impounded waters (lb./acre), and total P passing a given point from April through October (lb./mi.^{2} of drainage area) in 1968 and 1969

Location	Average concentration P in water (p.p.m.) 1968	1969	Standing crop P (lb./acre) 1968	1969	Total P, April-October (Lb./mi.^{2} drainage area) 1968	1969
Chattahoochee River:						
Bartlett's Ferry Reservoir:						
Input	0.283	0.336	16.75	17.47	242	560
Output	.215	.176			193	164
Lake Eufaula:						
Ft. Benning bridge	.984	.333	43.50	26.0	859	374
Cottonton bridge	.304	.425	9.90	17.4	265	470
Eufaula bridge	.063	.203	3.80	7.92	55	224
Walter F. George Dam . . .	.079	.086			68	95
Lake Seminole:						
Columbia Dam	.104	.069	2.87	1.97	129	89
River Mile 3	.122	.087			152	112
Flint River:						
Lake Seminole:						
Bainbridge bridge	.098	.442	3.15	6.64	86	388
River Mile 3	.150	.076	2.35	3.38	132	69
Spring creek mouth	.094	.132	3.10	3.48	70	103
Jim Woodruff Dam	.150	.136			128	148

river at points 100 or more miles upstream from this reservoir, and it would be reasoned that most of this N would have been dissipated before reaching this point. If we assume that each person eliminated 7 lb. N, as raw sewage, during this study period, the quantity of N entering this reservoir in 1968 was 20 percent of this possible domestic sewage load, but in 1969 it was over 80 percent of this sewage load.

If the lands included in this drainage area contained 1 percent organic matter, then the N content of the upper 6-inch layer would contain 1,000 lb. N per acre[4]. This means that each acre-inch of soil contains 160 lb. N, and erosion of less than 0.01 inch of soil could contribute an amount of N equal to the calculated quantity entering Bartlett's Ferry Reservoir in 1969.

The increase in output N content over input content can be attributed to lakeshore septic tanks plus contributions from sewage lagoons in Opelika, Ala., and from a large Pepperell Manufacturing Company plant.

These same N sources existed throughout Lakes Eufaula and Seminole on the Chattahoochee River, and to a lesser degree on the Flint arm of Lake Seminole. The Spring Creek drainage must be assumed to be entirely of agricultural origin, since no town dumps sewage in this stream. Certainly the N data on both Lakes Eufaula and Seminole appear more reasonable than those for Bartlett's Ferry Reservoir. It must be remembered also that the difference in quantity of N in 1968 and 1969 may have been largely due to the inclusion of suspended matter, N plus soluble nitrites, and nitrates in the 1969 data.

The P data for the Chattahoochee River system present a real problem in interpretation since our knowledge of the P sources is limited. If we assume that all sewered domestic sewage entering the river above Bartlett's Ferry Reservoir (600,000 P. E. at 1.75 lb. P/P.E. for period April through October) was removed through river mile 190, then we could account for 83 percent of the estimated P load. If we added a detergent P load of 3.5 lb. P/P.E. for April to October, the combine P input during this period would be 300 percent the estimated P load

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[4] Fried, M., and Broeshart, H. The soil-plant system in relation to inorganic nutrition. Academic Press, New York, 358 pp. 1967.

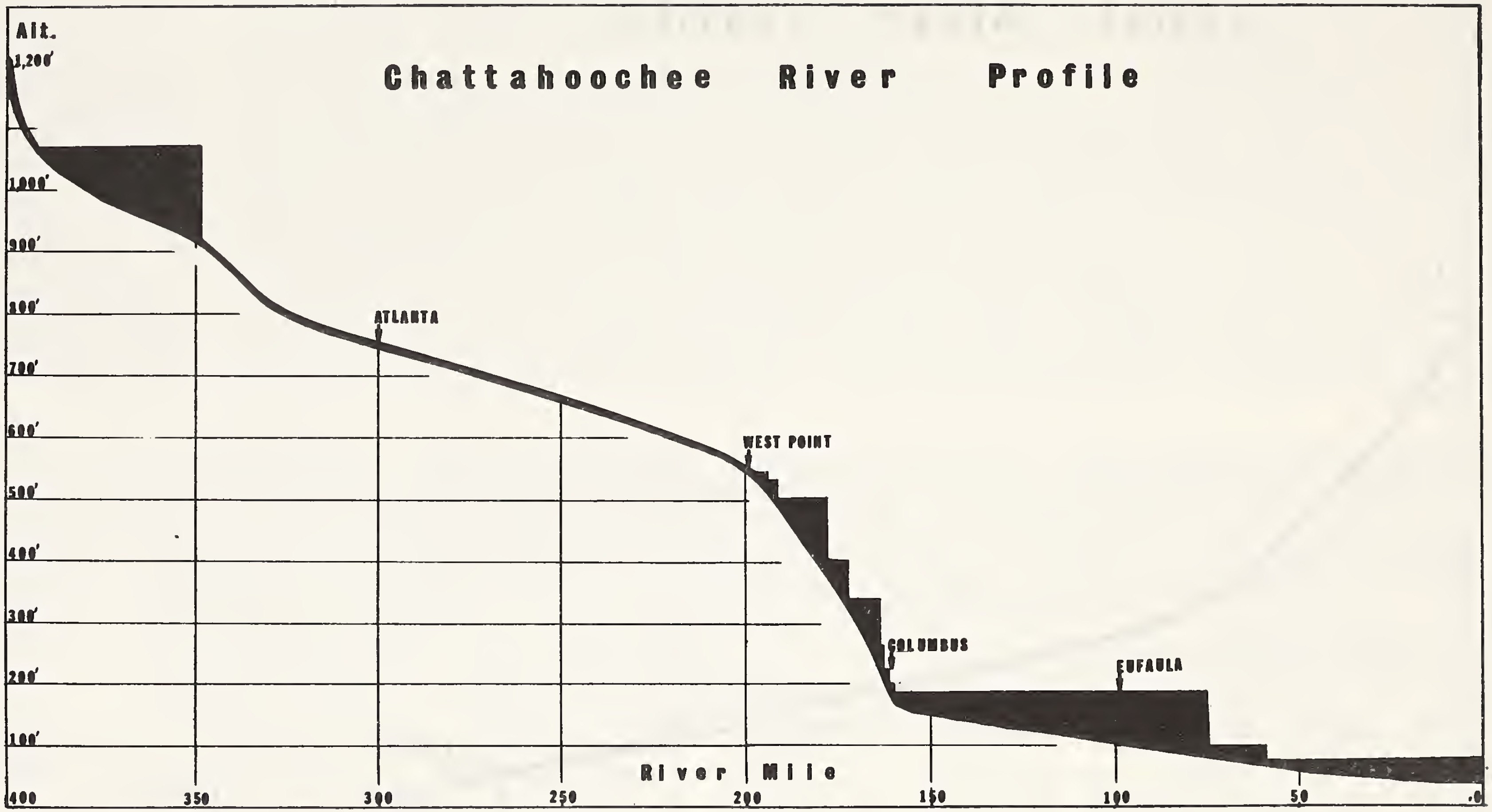

Figure 4. Profile of Chattahoochee river

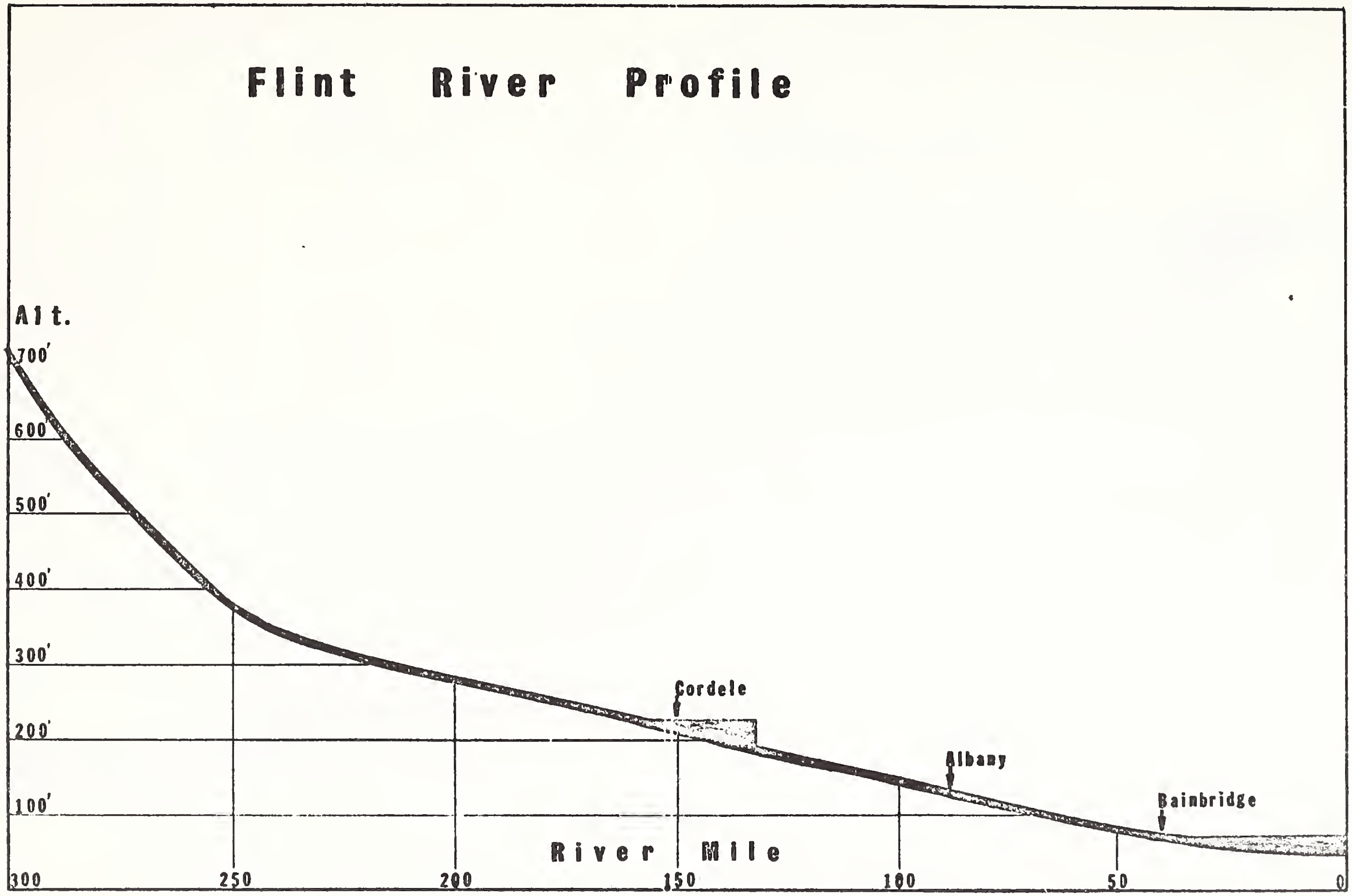

Figure 5. Profile of Flint River

passing river mi. 190 in 1968, and 150 percent of 1969 load. Of course this reasoning eliminates any retention of P by sewage treatment, or any permanent retention in river muds.

It has been shown that 30 percent of total P is retained by normal sewage treatment, but as much as 90 percent may be retained by additives such as $CaCO_3$ or Al_2 $(SO_4)_3$. Our data for 1969 show that possibly 70 percent of the P entering Bartlett's Ferry Reservoir was retained during the 7 month period, and data on Lake Eufaula in 1968 show about 65 percent P retention for a like period of time.

This suggests that probably the source of this P loading comes mainly from particulate P that originated at all points above river mile 190. It might also be speculated that much of this particulate loading could have resulted from poultry production and processing and that particles high in P content entered the river through surface runoff and were transported with time through the entire river and into the Gulf of Mexico. An examination of the river profile certainly suggests this to be possible. Also, the flow in this river is regulated such that almost daily flushing actions are in operation and the sediment is never permitted to stop moving. This seemingly is evident in the data.

As the river broadens and its gradient decreases, the soluble as well as the suspended matter P loading decreases. It would be suspected that P content in hydrosol would have increased in these lower reaches, but the data again indicate that the bottom in this lower river area is kept fairly clean. Sampling of bottom sediments was confined primarily to the old channel areas. However, when flooded plains on each side of the channel were checked and sampled it was found that sediments were confined to depression areas and that horizontal currents caused by wind action on the surface tended to move marginal area sediments into the deepest part of the impoundment where they were subjected to movement by stream currents.

The movement of N and P through the Flint River arm of Lake Seminole is presented separately for 2 reasons. First, this is a different river system, originating in a different soil type and with a more gentle river profile. Second, the drainage area is predominantly an agricultural region with a total sewered population of only 140,000.

The averaged quantity of total N entering Lake Seminole at Bainbridge, Ga., in 1968 or 1969 is unknown. The difference, however, in 1968 and 1969 data on soluble N is believed to be due to the inclusion of NO_2 and NO_3 analyses in these latter data. Too few estimates of N content of suspended matter are available for inclusion in 1969 data. From these few data, however, it appeared that the suspended matter N could double or even triple the total N load.

As mentioned previously, domestic sewage would not be expected to be an abundant source of N in this arm of Lake Seminole. Yet, if we consider the urbanized population equivalents (P.E.) at the upper region of Lake Eufaula (730,000) to those at the upper end of the Flint arm of Lake Seminole (140,000), we would expect the N loading to be less than 50 percent of what was estimated, indicating that other sources had to be contributing. In this case the major sources would be agricultural (peanuts, soybeans, shade tobacco, and livestock). Whatever the sources of N, its origin was above Bainbridge, Ga., as indicated by sampling at river mile 35 and by the preponderance of NO_3 ion over NH_3 ion in the water.

The P situation in this Flint River arm was similar to that indicated for N, with one exception. The soluble P content steadily declined throughout the length of Lake Seminole, and its concentration near the dam was 1/5 that at the input point.

The N and P content of hydrosol in this Flint River sector were approximately the same, 6 lb./acre/0.01-inch layer. This low content of elements, coupled with a low rate of deposition over the entire inundated area, indicates that the flushing action was operative on this segment of the reservoir, too.

The total N content of hydrosols from Bartlett's Ferry Reservoir and from Lakes Eufaula and Seminole were generally of the same magnitude for all locations and for both years. There does not appear to be any particular relationship between the quantity of N passing through an area and the quantity of N present in the bottom muds. Thus, if the source of soluble N was from particulate matter, this material was apparently being transported at a higher level in the river channel than was included in the hydrosol samples.

The identifiable assimilation of N and P by the biomass in Bartlett's Ferry Reservoir and Lake Eufaula was restricted to those quantities present in the fish populations. The averaged quantity of N present in the standing crop of fish was 4.82 lb./acre, and the quantity of P present in the fish population was 1.51 lb./acre. The total standing crops of N and P in the entire fish populations in Bartlett's Ferry Reservoir and Lake Eufaula are given below:

Location	N-(lb.)	P-(lb.)
Bartlett's Ferry	28,197	8,833
Lake Eufaula	216,900	67,950

No estimate of the quantities of N and P present in phytoplankton was made, since no technique was available to separate living plankton from other suspended matter. The growths of rooted aquatic plants in both impoundments was so limited (less than 10 acres of plants in over 50,000 acres of impoundment) that no estimates of their N or P assimilation are included in this review.

The assimilation of N and P by the biomass in Lake Seminole will be presented separately for the Chattahoochee, Flint, and Spring Creek Arms.

Location	Biomass component	Standing crop (lb.)			
		N		P	
		1968	1969	1968	1969
Chattahoochee arm:					
	Fish	70,875	70,875	22,140	22,140
	Aquatic plants	93,320	64,042	6,515	10,290
Fint arm:					
	Fish	76,125	76,125	23,780	23,780
	Aquatic plants	140,180	91,287	11,780	31,232
Spring Creek arm:					
	Fish	39,375	39,375	12,300	12,300
	Aquatic plants	344,140	352,200	23,800	21,920

On a per-acre basis, the quantities of N and P contained in the summertime standing crop of plants in portions of Lake Seminole were as follows:

Location	N		P	
	1968	1969	1968	1969
		Lb. per acre		
Chattahooche arm . .	12.1	10.0	2.1	2.4
Flint arm	15.0	11.5	2.4	3.8
Spring Creek arm . .	51.0	52.2	4.8	4.6

The tremendous increased N content in Spring Creek arm resulted from a heavy underwater growth of eurasian milfoil.

SUMMARY

A study was conducted from April through October, 1968 and 1969 in three reservoirs on Chattahoochee and Flint Rivers, in which the input-storage-output of N and P were determined.

Bartlett's Ferry Reservoir, located on the Chattahoochee River between miles 180 and 190 has a drainage area (d.a.) of 4,000 sq. mi., an area of 5,850 acres, and an average depth of 25 ft. The input N for the 1968 study period was 230 lb./mi.^{2}. The storage of N in hydrosol was 7.83 lb./acre/0.01-inch layer. In 1969 study period the input N was 827 lb./mi.^{2} d.a. The storage of N in hydrosol was 6.03 lb./acre/0.01-inch layer.

One cause of the increased N content in waters during 1969 was the inclusion of NH_3 + NO_2 + NO_3 ions as soluble N plus total N in suspended matter, whereas in 1968 it included only the NH_3 ion.

While all sources of N to this reservoir are unknown, domestic sewage was undoubtedly a major contributor. It appears likely the poultry production and processing might also have contributed particulate matter high in N that was moved sufficiently rapidly down the river to contribute to this problem.

The P input in 1968 was 242 lb./mi.^{2} d.a., and the ouput was 193 lb./mi^2 d.a. The hydrosol content was 7.3 lb. P/acre/0.01-inch layer. The 1969 input of P was 560 lb./mi.^{2} d.a., and the output was 164 lb./mi.^{2} d.a. The 1969 hydrosol content was 11.2 lb. P/acre/0.01-inch.

Major P sources included domestic sewage, including detergents, and varied industrial and agricultural operations. There was some indication of a correlation of higher P input with higher P recovery from hydrosol.

Lake Eufaula, located between river miles 75 and 160 has a total d.a. of 7,460 sq. mi., a surface area of 45,000 acres, and an average depth of 20.9 ft. For a better understanding of input data, the lake was divided into an upper region (5,000 sq. mi. d.a.), a middle region (5,535 sq. mi. d.a.), and a lower portion (6,660 sq. mi. d.a.).

The N and P input-output/sq. mi. d.a. for the 3 regions were as follows:

Region:	N		P	
	1968	1969	1968	1969
Upper — In	.178	771	859	374
Middle — In	.152	565	265	470
Lower — In	.158	522	55	224
Dam — Out	.168	429	68	95

The N and P content of the hydrosol in lb./acre/0.01-inch layer was as follows:

	N		P	
Region:	1968	1969	1968	1969
Upper	5.77	6.67	7.1	8.1
Middle	8.60	8.60	5.6	11.3
Lower	6.50	10.00	2.5	9.5

Lake Seminole is the lower reservoir and extends from Chattahoochee River mile 50 to 0 and Flint River mile 30 to 0. The N and P input-output data on these 2 river systems as lb./sq. mi. d.a. are given below:

	N		P	
	1968	1969	1968	1969
River arm:				
Chattahoochee:				
In	226	309	129	89
Out	267	379	152	112
Flint:				
In	157	347	86	388
Out	183	295	132	69

The N and P content of hydrosol in lb./acre/0.01-inch layer are given below:

	N		P	
	1968	1969	1968	1969
River arm:				
Chattahoochee	8.6	8.3	—	2.7
Flint	7.0	5.8	1.3	0.7

All input sources of N and P that entered these reservoirs included some domestic sewage and industrial effluents plus agricultural runoffs. In all cases it appeared that the major portion of the N and P entered the river systems in particulate form and was generally moved downstream in this manner. Some portion of this particulate form of N and P gradually went into solution as it proceeded down the rivers.

The standing crops of N and P (expressed as lb./surface acre) that were assimilated by the biomass in the three impoundments were as follows:

	N		P	
	1968	1969	1968	1969
Impoundment:				
Bartless's Ferry Reservoir	4.8		1.5	
Lake Eufaula	4.7		1.5	
Lake Seminole:				
Chattahoochee arm	12.1	10.0	2.1	2.4
Flint arm	15.0	11.5	2.4	3.1
Spring Creek arm	51.1	39.0	4.8	4.7

LAND DISPOSAL OF ANIMAL WASTES IN TEXAS

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(Presented by R. E. Stewart)

INTRODUCTION

The average American's increasing preference for meat has been nothing short of amazing. The per capita consumption of beef in the United States has increased almost 75 percent since 1950, while the per capita consumption of pork has declined slightly. This increased preference for beef, combined with an increasing population, has caused the number of cattle and calves on farms to increase dramatically.

Texas is the leading beef cattle producing State, accounting for 12 percent of the cattle and calves on farms of the United States on January 1, 1968. Texas also accounts for 40 percent or more of the annual grain sorghum production in the United States. These are two of the basic resources necessary for cattle feeding and, when combined with the large demand for beef, have led to the amazing growth of the cattle-feeding industry in Texas during the past decade. This growth has been characterized by an expansion of cattle-feeding facilities with a capacity of 1,000 head or more. Texas feedlots with a capacity of 1,000 head or more increased from 61 in 1958 to 275 in 1968, an increase of 350 percent. During this same period, the capacities of the large feedlots increased 670 percent, from 160,000 head to 1,229,000 head.

As impressive as the figures for the entire State of Texas are, the figures for the growth of the cattle feeding industry in the

Panhandle-Southern High Plains area of Texas are even more dramatic. Dietrich (1968) indicates that the Panhandle-Southern High Plains area of Texas produced approximately two-thirds of the State's grain sorghum and had slightly more than 50 percent of the cattle placed on feed in Texas feedlots during 1966-67. A recent survey by Southwestern Public Service Company (1969) of the territory in the Panhandle-Southern High Plains inside their service area indicated that as of March 31, 1969, there were 163 cattle feedlots, and 111 of these had capacities in excess of 1,000 head. The at-one-time feedlot capacity of these 163 feedlots was 989,356 head, with an annual capacity of 2,431,231 head.

The growth of the cattle feeding industry, combined with the trend toward mass production of beef in confinement feeding operations, provides a potential for pollution of the soil, air, and water resources of a region. As a rule of thumb, two tons per year of a semicomposted manure with a 50-percent moisture content accumulates for each head of feedlot capacity. Thus, a 10,000-head feedlot must be prepared to dispose of 20,000 tons of manure per year. Adequate waste disposal is becoming a major problem for the cattle feeding industry in Texas. These wastes must be disposed of in a manner that will not pollute the soil and water resources.

Most feedlot operators would like to see the manure spread onto farmland in the vicinity of the feedlot, and at this time they are willing to give manure to farmers at no cost. However, the feedlot operation still expects the farmer to pay for hauling and spreading the manure onto the farm. Loading and hauling manure in the Hereford, Tex., area costs $1.50 to $2.00 per ton plus 5 cents per ton-mile. Assuming a common field application rate of 10 tons per acre and an average hauling distance of four miles, the cost of a manure application would be $17.00 to $22.00 per acre. Many farmers find the economics of using manure questionable. In any event, farmers are not accepting the manure, and many feedlot operators are being forced to stockpile manure in the immediate vicinity of the lot. Loading, hauling, and dumping costs range from 35 cents to $1.00 per ton for the stockpiling operation.

Deep plowing to alleviate specific soil problems has been investigated numerous times during the past 50 years. Hauser and Taylor (1964) evaluated deep-plowing treatments on Pullman silty clay loam near Amarillo, Tex. Mach and others (1967) investigated soil-profile modification by backhoe mixing and deep plowing. Lyles and others (1963) reported the soil-mixing characteristics of three deep-tillage plows. Resmussen and others (1964) indicated an improvement of slick-spot soils in southwestern Idaho, using deep-tillage techniques. Burnett and Tackett (1968) have shown that deep plowing Houston black clay improved root proliferation. These investigations have been primarily interested in deep tillage for greater crop production. Studies to evaluate deep plowing as a modified landfill for disposal of wastes are virtually nil. Reed (1966) evaluated the Plow-Furrow-Cover method for the disposal of poultry manure.

To assist the Texas feedlot operator in finding a pragmatic solution to his manure disposal problem, a study has initiated in the summer of 1970 to investigate systems of deep-plowing large quantities of manure into the soil. The objectives of this study were (1) to evaluate the ability of various tillage equipment to plow under up to 900 tons per acre of manure and cover with sufficient soil to eliminate odors, (2) to evaluate the deep plowing disposal technique for possible pollution of surface water and groundwater, and (3) to evaluate two different soils as manure disposal mediums.

EXPERIMENTAL DESIGN

The deep plowing experiments were conducted on substations of the Texas Agricultural Experiment Station at El Paso and Pecos, Tex. The soil in the research plots at El Paso is described as a Vinton fine sandy loam with low moisture-and fertility-hold capacity. From 18 inches to 10 feet, the soil is very sandy, with the water table fluctuating between 8 to 12 feet below land surface. The soil at Pecos is a Hoban silty clay loam. Except for some isolated instances of perched groundwater, the water-table depth at Pecos is greater than 100 feet.

Manure for the deep-plowing operation was available from beef feedlots at El Paso and Pecos. Both feedlots were feeding high-concentrate rations typical of commercial feedlots in western Texas. Table 1 shows the moisture content and chemical analyses of the manure used at both deep-plowing sites. Manure application rates of 0, 300, 600, and 900 tons per acre were used. These are the recorded weights of the manure as hauled to each plot. They will be used throughout this paper to refer to the manure treatments. However, as indicated in table 1, the moisture content of the manure at both locations was approximately 50 percent on a wet weight basis. Thus, the application rates are approximately equivalent to 0, 150, 300, and 450 tons per acre of dry manure. After spreading and leveling, the application rates of 300, 600, and 900 tons per acre resulted in manure depths of approximately three, six, and nine inches, respectively.

Table 1. Chemical content of manure used at El Paso and Pecos deep-plowing sites

Location	Moisture content (percent of wet weight)	Chemical content (percent of dry weight			
		N	P_2O_5	K_2O	C1
El Paso	51	3.5	1.5	2.7	1.5
Pecos	48	2.3	1.7	11.7	1.1

The deep plowing equipment consisted of: (1) a 30-inch, single-bottom, rollover moldboard, plowing 30 to 36 inches deep; (2) an 18-inch, 4-bottom, rollover moldboard, plowing 21 inches deep; (3) a trencher with a 27-inch digger wheel, working 30 inches deep; and (4) a 50-inch disk plow with three chromium-plated disks, plowing 21 inches deep. A total of 20 treatments were used, with no repetitions. Each of the plots was approximately 0.1 acre in size, and water was available for irrigation purposes.

RESULTS

Ability of Equipment to Plow under Manure

30-inch Moldboard. The plow was an old plow requiring some repair work prior to use. A crawler type tractor with approximately 220 horsepower was required to pull the plow. At El Paso the plowing operation consisted of the following steps: (1) an initial pass was made with the plow to open a furrow, (2) manure was bladed into the open furrow, (3) another pass with the plow was made to cover the manure and open a new furrow, and (4) steps two and three were repeated. Since one wheel of the plow ran in the furrow, the blading of manure into the furrow adversely influenced the operation of the plow. At Pecos, a blade was mounted on the plow immediately in front of the moldboard to move manure into the furrow. This was much more desirable than the operation at El Paso. The plow did not shed soil completely at either El Paso or Pecos. Figure 1 shows the 30-inch moldboard plowing in the 900-ton-per-acre plot at Pecos. The 30-inch moldboard plow effectively turned under all manure treatments.

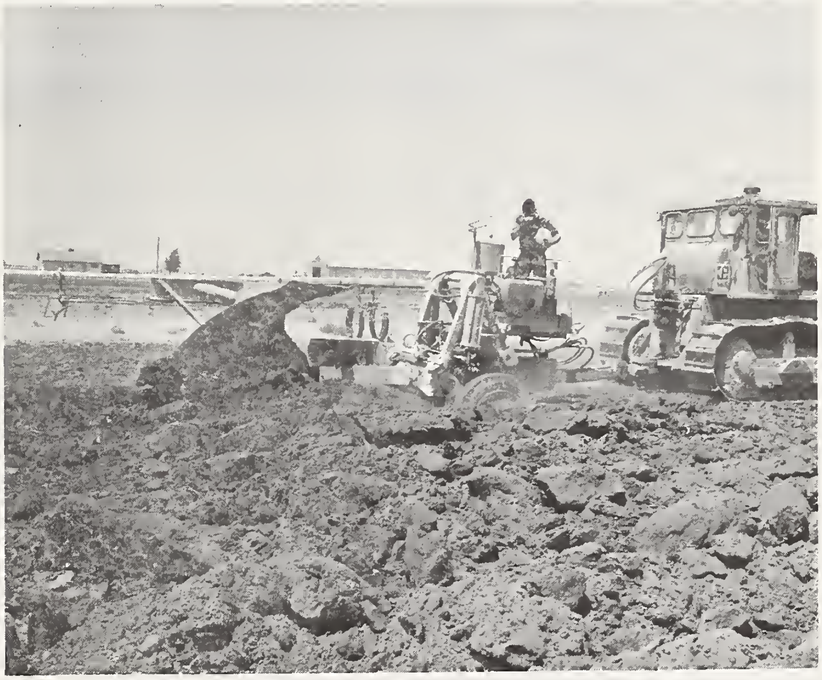

Figure 1. The 30-inch moldboard plowing under 900 tons of manure per acre at Pecos, Texas. Note the blades attached to the plow for moving manure into the furrow.

18-inch Moldboard. The 900 ton per acre treatment and its resulting nine inches of manure on the surface was beyond the capacity of the 18-inch moldboard for complete turning and coverage. This plow left a large amount of manure on the surface of the 900-ton-per-acre plot. Even on the 600-ton-per-acre plot, a significant amount of manure was left exposed on the surface. However, this plow did an excellent job of coverage in the 300-ton-per-acre plot. Figure 2 shows the 18-inch plow in operation at El Paso and the soil surface condition after plowing in the 600-ton-per-acre plot. From these tests, the 18-inch moldboard would be limited to manure rates below 600 tons per acre.

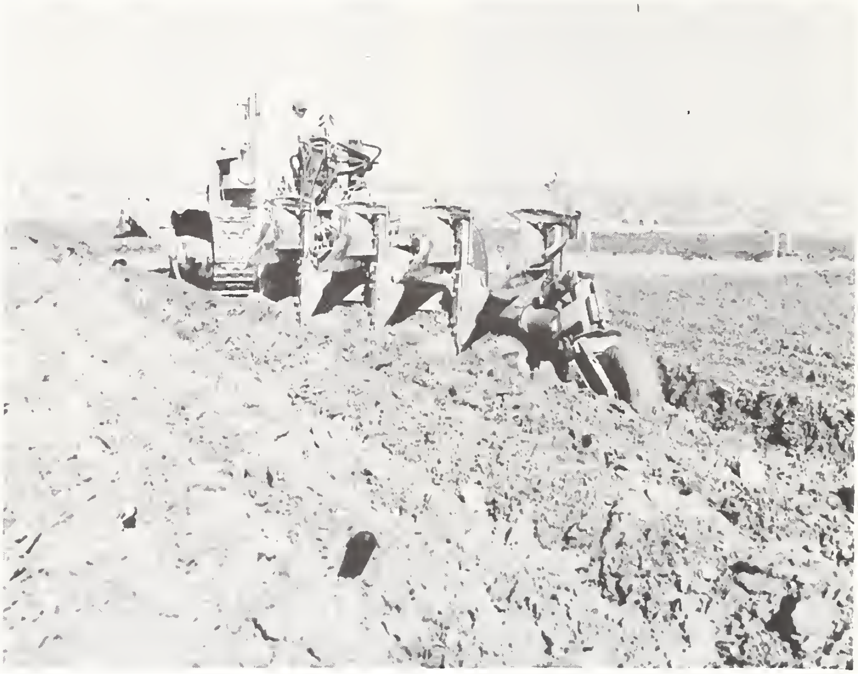

Figure 2. The 18-inch moldboard plowing under 600 tons of manure per acre at El Paso, Texas.

27-inch Trencher. The plan of operation with the 27-inch trencher was to open a trench and carry the soil from this trench into an open trench beside the machine as shown in Figure 3. The trencher depth was maintained to cut through the manure plus 30 inches of soil. The machine worked well and the appearance of mixed soil and manure was extremely good. Deeper soil penetration and larger amounts of manure could undoubtedly have been used with this machine.

50-inch disk plow. In Figure 4, the 50-inch disk plow is shown plowing to a depth of 21 inches. The disks did not shed soil well, which resulted in two things: (1) The soil was not completely turned and (2) the disks tended to ride out of the ground, forcing the plow to take a larger width of cut than normal. Frequent cleaning of the disks was required. In other soils that are more conducive to shedding, this would not have been a problem. Overall, the 50-inch disk treatment was less than satisfactory, and considerable manure was left on the surface. However, with proper shedding of the soil, the disk plow would have done as good a job as the 30-inch moldboard in plowing under 600 tons of manure per acre.

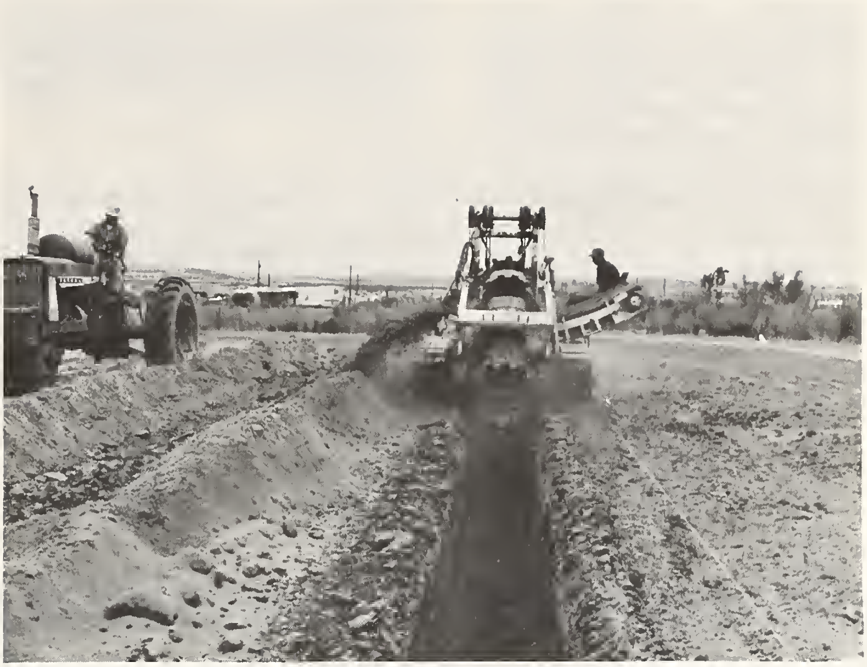

Figure 3. The 27-inch trencher turning under 900 tons of manure per acre at El Paso, Tex.

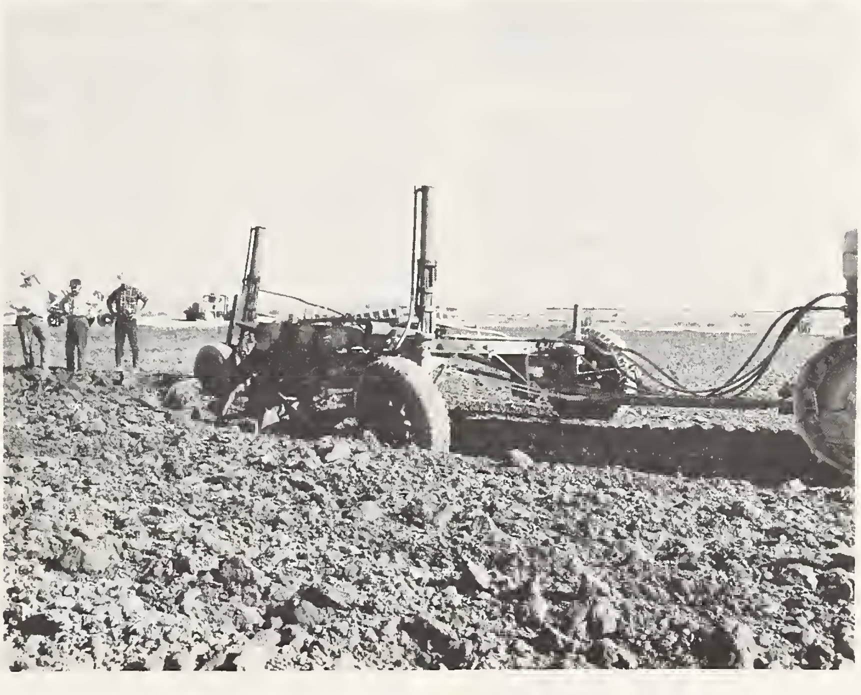

Figure 4. The 50-inch disk plowing under 900 tons of manure per acre at Pecos, Tex.

Costs of Deep-Plowing Manure

The tillage equipment used in this study is available in western Texas. As a part of this study, several deep plowing contractors were contacted and their contract price for deep plowing obtained. These data are summarized in table 2. They do not include the cost of spreading and leveling the manure. The $560 per acre cost for the trencher was obtained by assuming a 27-inch cut, a cutting capacity of 10 feet per minute, and a contract cost of $17.50 per hour.

Table 2. Costs of deep plowing manure for various application rates in western Texas

Tillage equipment	Contract cost (dollars per acre)	Cost of Plowing under manure (dollars per ton)		
		300 tons per acre	600 tons per acre	900 tons per acre
30-in. moldboard	40.00	0.133	0.067	0.045
18-in. moldboard	12.00–15.00	0.04–0.05	0.02–0.025	–
27-in. trencher	560.00	1.86	0.93	0.62
50-in. disk	12.50	0.042	0.021	–

From an analysis of the equipment's ability to plow under manure and the costs indicated in table 2, use of the 18-inch moldboard and 50-inch disk would be recommended for manure applications of 300 tons per acre. The 30-inch moldboard and 50-inch disk are recommended for deep plowing manure at rates of 600 tons per acre. For manure application rates of 900 tons per acre, use of the 30-inch moldboard is recommended. The cost of using the trencher is much greater than that of using the conventional tillage equipment. However, for manure application rates in excess of 900 tons per acre, use of the trencher is recommended.

As indicated in table 2, the cost of plowing under 300 tons per acre of manure with the 18-inch moldboard and 50-inch disk is the same as plowing under 900 tons per acre with the 30-inch moldboard. The possibility exists that the 300 ton rate can be recycled more often than the 900-ton rate. For this reason, the 18-inch plow and 300-ton per acre application rate warrant considerable attention.

Quality of Surface Water Runoff

At this time, no rainfall runoff of sufficient size to warrant analysis has occurred at either El Paso of Pecos. However, the plots at El Paso were irrigated in June and July of 1970, and the plots at Pecos were irrigated in August of 1970. Samples of runoff were collected from these irrigations and analyzed for pollutants. Concentrations of ammonia, total phosphate, and total organic carbon are shown in table 3. Tests for coliforms were made by the multiple-tube fermentation technique, and these results are shown in table 4.

The results in tables 3 and 4 indicate an inconsistency in the 900-ton treatment at Pecos. This is believed to be the result of unusual weather conditions on the afternoon these plots were irrigated. Extremely strong winds (40 to 50 miles per hour) were blowing across these plots and tended to hold back sediment and debris that would normally have passed through the flume and water sampler. This resulted in virtually clear water coming off of the plots and a corresponding decrease in the amount of pollutants.

These data indicate that the greatest opportunity for polluting surface water is by ammonia. For the larger manure application rates, all tillage treatments show an increase in ammonia content. The results in table 3 also indicate that any surface water pollution created by deep plowing manure will be reduced with time. For instance, at El Paso the ammonia content in runoff was reduced significantly between June and July. Other constituents show a like trend. Very little organic pollution, as measured by total organic carbon, was indicated for any of the tillage treatments. Although the confirmed coliforms show an increase over the check for all treatments, the presence of fecal coliforms was virtually nonexistent in most treatments.

The 18-inch moldboard can safely plow under 300 tons of manure per acre without polluting surface water runoff. However, the use of the 18-inch plow in the 600- and 900-ton per acre plots resulted in an increase of all chemical constituents. For the higher manure application rates, use of the trencher or 30-inch moldboard is recommended to minimize pollution of surface water runoff.

Table 3. Chemical quality of irrigation water runoff from deep plowed manure plots

Manure application rate (tons per acre)	18-inch plow (El Paso)		Trencher (El Paso)		30-inch plow (El Paso)		30-inch plow (Pecos)	50-inch disk (Pecos)
	June	July	June	July	June	July	August	August
				Ammonia (mg. per liter)				
0	0.10	0.88	0.00	2.02	–	1.71	5.74	4.4
300	0.00	7.20	0.00	3.45	–	6.25	7.38	7.28
600	67.50	24.30	68.12	15.75	2.68	23.10	25.2	62.7
900	140.0	35.25	5.04	22.05	69.0	25.80	4.77[1]	14.3[1]
				Total phosphate (mg. per liter)				
0	0.87	2.34	1.57	1.20	–	2.02	1.71	1.34
300	1.30	1.57	2.76	1.66	–	1.38	10.17	9.9
600	7.02	4.95	6.39	1.30	7.73	1.91	11.07	14.58
900	14.94	4.50	5.76	2.02	7.29	3.42	1.54[1]	1.20[1]
				Total organic carbon (mg. per liter)				
0	8	19	0	12	–	15	12	8
300	6	17	13	10	–	24	4	11
600	38	26	34	20	35	10	12	24
900	54	38	41	17	47	22	6[1]	5[1]

[1] These values are believed to have been reduced by a severe windstorm during the irrigation of these plots.

Table 4. **Coliform counts of irrigation runoff from deep plowed manure plots**

Manure application rate (tons per acre)	18-inch plow (El Paso)		Trencher (El Paso)		30-inch plow (El Paso)		30-inch plow (Pecos)	50-inch disk (Pecos)
	June	July	June	July	June	July	August	August
CONFIRMED COLIFORM (MOST PROBABLE NUMBER)								
0	5420	1609	790	542	–	4900	33	490
300	16090	7900	5420	24000	–	34800	16090	3480
600	24000	3300	24000	54200	24000	24000	54200	5420
900	160900	54200	34800	34800	24000	24800	5420[1]	1720[1]
FECAL COLIFORM (MOST PROBABLE NUMBER)								
0	460	4	220	17	–	0	0	0
300	170	500	130	348	–	0	20	0
600	1410	0	1090	0	700	0	0	0
900	9180	800	700	0	1720	200	0[1]	20[1]

[1] These values are believed to have been reduced by a severe windstorm during the irrigation of these plots.

Quality of Groundwater

Wells have been drilled in the plots at El Paso to take samples of groundwater. Also, soil solution access tubes have been installed at depths of two, three, and four feet below the plots. A vacuum is applied to each tube, and samples of the soil-solution extract are taken after each irrigation. Insufficient time has elapsed to draw any definite conclusions concerning groundwater pollution. Preliminary results are shown in tables 5 and 6.

Table 5. **Chemical quality of soil-solution extracts taken from two, three and four feet below manure plots at El Paso, Tex.**

Depth in feet	Check	300 tons/acre	600 tons/acre	900 tons/acre
TOTAL ORGANIC CARBON (MG./1.)				
2	17	137	741	930
3	21	68	1298	2567
4	24	53	720	2623
TOTAL PHOSPHATE (MG./1.)				
2	1.8	14.2	4.5	9.2
3	1.8	8.6	8.1	15.2
4	1.8	–	7.3	14.8
AMMONIUM (MG./1.)				
2	0.3	135	500	214
3	2.7	125	221	382
4	0.4	108	26	31
NITRATES (MG./1.)				
2	1.0	65	13	4
3	2.0	62	26	10
4	4.7	153	52	13
CHLORIDES (MG./1.)				
2	111	768	729	1307
3	84	705	581	1700
4	100	–	895	2612

Table 6. Chemical quality of soil solution extracts taken from two, three, and four feet below manure plots at Pecos, Tex.

Depth in feet	Check	300 tons/acre	600 tons/acre	900 tons/acre
		TOTAL ORGANIC CARBON (MG./1.)		
2	3	1233	849	793
3	4	981	377	28
4	7	118	65	5
		TOTAL PHOSPHATE (MG./1.)		
2	8.8	11.7	9.7	7.8
3	5.4	9.6	4.8	10.1
4	4.4	10.1	8.9	10.8
		AMMONIUM (MG./1.)		
2	0.8	632	138	305
3	2.2	301	85	4
4	0.8	20	32	1
		NITRATES (MG./1.)		
2	70	40	20	50
3	26	70	22	48
4	10	21	18	22
		CHLORIDES (MG./1.)		
2	2482	7022	4913	5062
3	1861	5385	4417	2194
4	2159	4317	3325	1578

Differences in the two soils are apparent from these data. The silty clay loam soil at Pecos reduced the concentration of all contaminants by the time water passed the four-foot depth. However, the fine sandy loam soil at El Paso has a very sandy subsoil beginning at about 18 inches deep. Chlorides, nitrates, phosphates and total organic carbon at El Paso showed an increase in concentration at the four foot depth.

At El Paso, there is an indication that denitrification may be taking place beneath the 900-ton-per-acre plot. Sufficient carbon is available as a food source for soil microorganisms, and with anaerobic conditions denitrification could occur. At this time, a buildup of chloride appears to be the greatest groundwater-pollution threat. Additional analysis of the groundwater-pollution problem will be needed before definite conclusions can be made.

Crop Growth

During the fall of 1970, barley, sugarbeets, and sweetclover were planted at El Paso. The barley has done very well on all plots, including the 900 ton per acre treatment. Sugarbeets did not come up to a stand on any plots, including the check. Sweetclover is up to a good stand on all manure treatments where the trencher was used, but it did not come up very well on the 18-inch-moldboard and 30-inch-moldboard plots. At Pecos, fall crops of barley, alfalfa, and sugarbeets were planted, and at this time all crops are up to a stand and growing. No yield data from these crops are presently available.

CONCLUSIONS

Rates of manure up to 900 tons per acre can be plowed under with a 30-inch moldboard plow at a minimum cost of 4.5 cents per ton. In soils conducive to shedding, the 50-inch disk plow should be able to plow under at least 600 tons per acre of manure with a minimum cost of 2.1 cents per ton. The 18-inch moldboard is limited to about 300 tons of manure per acre at a cost of 4.0 cents to 5.0 cents per ton. The trencher seems most versatile from the standpoint of high manure-application rates and soil penetration depths. The cost of the trencher is high and in the order of 62 cents per ton at the 900-ton-per-acre rate. The complete mixing of soil and manure as done by the trencher is impressive, and manure-application rates considerably larger than 900 tons per acre could probably be handled by the trencher. At this time, the water-quality program shows no serious pollution problem for surface water runoff. Crop growth on all manure treatments has been achieved.

References

1. Burnett, Earl and Tackett, J. L. 1968. Effect of soil profile modification on plant root development. Presented 9th Internl. Soil Congr., Adelaide, Australia, August 1968.
2. Dietrich, R. A. 1968. The Texas-Oklahoma cattle feeding industry, structure and operational characteristics. Tex. Agr. Expt. Sta. Bull. B-1079: 47 pp.
3. Hauser, V. L. and Taylor, H. M. 1964. Evaluation of deep-tillage treatments on a slowly permeable soil. Amer. Soc. Agr. Engin. Trans. ASAE 7(2): 134-136, 141.
4. Lyles, Leon, Heilman, M. D., and Thomas, J. R. 1963. Soil-mixing characteristics of three deep-tillage plows. J. Soil Water Conserv. 18: 150-152.
5. Mach, Stephen J., Horner, G. M., Cox, L. M., and Cary, E. E. 1967. Soil profile modification by backhoe mixing and deep plowing. Amer. Soc. Agr. Engin. Trans. ASAE 10(6): 775-779.
6. Rasmussen, W. W., Lewis, G. C., and Fosberg, M. A. 1964. Improvement of the Chilcott-Sebree (solodized-Solonetz) slick spot soils in southwestern Idaho. U.S. Dept. Agr., Agr. Res. Serv., ARS 49-91: 39 pp.
7. Reed, C. H. 1966. Disposal of poultry manure by Plow-Furrow-Cover method. Proc. Natl. Symp. Animal Waste Management. Amer. Soc. Agr. Engin. ASAE Publ. SP-0366: 52-53.
8. Southwestern Public Service Co. 1969. 1969 fed cattle resources survey. Agr. Develop. Dept. Southwestern Public Serv. Co., Amarillo, Tex.

AN OVERVIEW OF THE POLLUTION SITUATION AND CORRECTIVE ACTIONS

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There is immense publicity concerning pollution. Vast sums of money are and will be made available for research, demonstration, and evaluation of pollution abatement methods. In addition, sharp teeth are very much in evidence in the Public Laws governing this aspect of our environmental concern. The combination of these factors does not leave room for choice. Action is the obvious response. Agriculture must be prepared to make the necessary pollution control adjustments right along with and as these adjustments are made in urban and industrial waste situations. In modern society when one group reacts to come within acceptable limits, other groups must also expect to do this. Accordingly, the time lag for making adjustments has diminished and rather significantly during the past 12 months.

In any production process when a byproduct cannot be recycled it becomes a potential source of pollution. Agriculture produces some of these byproducts and agriculture is affected by the byproducts of other processes. There are two procedures for recycling. One involves moving the byproduct through a process or processes, then marketing the processed material to recover costs and sometimes make a profit. The second procedure involves processing the waste so that it can be recycled at a level of degradation that is acceptable in the environment but which is not in a salable form. This means that an expense must be passed along to the consumer of the major product. The growing national economy and the increasing population only intensify the already complex situation, so it is certainly appropriate to examine some causes and effects of pollution sources.

Odors, Dust, Flies

These are nuisance byproducts of many agricultural productions and practices. Their origin is often a result of poor management practices and a failure to accept the fact that what was once routinely overlooked must now be corrected. There is additionally a question of nuisances, particularly malodors, arising from processing plants such as rendering plants for poultry and catfish and the huge kraft-pulping industry in the southern section of States. Dust from poultry ventilating systems and processing plants and flies from such production practices as caged-layers are already being reported to enforcing authorities for corrective action.

The fly problem on egg-producing poultry farms is one example of a pollution source that can be corrected through improved production practices, better housekeeping, approved spraying schedules, and the proper management of manure. Some poultrymen are using deep dry pits under the cages and promoting waste stabilization through forced aeration of the area. Other poultrymen collect the wastes frequently and transport them to a portable tank for eventual return to the land. The return-technique involves opening a furrow, depositing the waste, then recovering the furrow in a once-over-the-field operation. The immediate covering avoids odor and fly nuisances.

Odor abatement is an example of byproduct processing where an expense is incurred but the output product is not marketable. It just smells better, and eventually the consumer of the principal product must share in the cost. Odor is one of the most elusive problems encountered in the fields of air and water pollution. The human nose has the ability to detect odors in extremely small concentrations, such as 0.001 p.p.m. These concentrations are too small for measurement by physical instrumentation. As a consequence, research is slowed somewhat, but an evaluation in quantitative terms is possible by utilizing the judgment of human panels governed by standardized procedures. An added challenge is presented by the fact that the response of the human olfactory system is logarithmic:

$$P = K \operatorname{Log} S$$

where P is the response, K is a constant, and S is the concentration of the odor in p.p.m. Accordingly, if P, the response, is to be reduced by 80 percent, S must reduce by a factor of 10,000; meaning that odor concentrations must be greatly reduced before they become acceptable.

Within this type of quantitative measure and challenge, several procedures for odor abatement merit particular attention.

(1) Oxidation: an effort to oxidize the organic odorants by flame combustion in an afterburner or existing burners, which also might include chemical oxidation by gas-gas contact.

(2) Water scrubbing: A most effective procedure, which might be improved even more by water treatment through mechanical aeration and chemicals.

(3) Byproduct control: Undoubtedly, many odors can be minimized by management of the input product as to mixture, moisture, temperature, and state of decay.

(4) Green buffer zones: There is always a solution involving zoning for efficient land use and surrounding by bands of green vegetable growth. Even more unconventional would be to produce and process certain products in a remote geographical location such as the Western desert.

Unmanaged Manure

About 2 billion tons of manure are produced by livestock in the USA each year. It is safe to say that some goes unmanaged. In the State of Georgia, for example, cattle, swine, broilers, layers, and turkeys produce about 159 million pounds of manure each day (table 1). If each pound as it is produced is moved 10 feet in one hour, and this continues for 24 hours each day, it would require a 2,000 hp. motor operating continuously or 48,000 horsepower hours per day.

Table 1. Daily production of manure from livestock in Georgia, 1971

Livestock	Manure production
	Lb.
Cattle	128,000,000
Swine	14,700.000
Broilers	6,000,000
Layers	10,000,000
Turkeys	94,000
Total	158,794,000

The concept that manure must be treated in a positive way and at a cost is not easy to accept, and the tendency to push it aside is very strong.

Runoff from beef cattle feedlots is a pollution source of considerable consequence. Even some lots with a treatment method are violated by heavy rains. The runoff water must be intercepted and contained, or better yet is the covered lot with slotted floors.

Composting is common around some poultry and dairy barns. This is minimum management as practiced and is subject to runoff, odors, and flies.

Overloaded manure pits, as well as stacks awaiting transport to pastures and fields, are common. Many hold to the belief that manure management via return to the land as fertilizer is the waste-management technique to follow. It must be recognized that this technique assumes adequate land, zero nuisance following application, good weather, and no equipment breakdowns.

Another consideration that prompted my assigning field spreading as "unmanaged" arises from the fact that modern technological innovations have reduced the cost of commercial fertilizers, which results in a depreciation of the relative value of animal manure. Also labor costs for recycling wastes to the land, along with the social pressure to upgrade environmental quality depreciate the use of animal manure as a fertilizer. Nuisance factors alone will prohibit this practice in some localities.

There is also the potential that the environment may be contaminated by disease as a result of unmanaged manure, both as a result of runoff and via plants or animals in fields receiving the wastes. There is also a broad spectrum of antibiotics which are of concern. The needs in this area are complex and involve monitoring equipment, additional knowledge about disease transmission, and restrictions or recycling untreated manure to the fields.

The obvious solution to unmanaged manure is to manage it. Sufficient information is available for the design and operation of primary treatment systems so that several alternatives can be presented for each manure management situation. There is a need for more information or certain secondary treatment systems where ultimate safe and economical disposal of the waste must be assured. The alternatives for treating agricultural wastes that are believed to be most important to the Southern Region are described in the following sections.

Unit 1. Aerobic lagoon, naturally aerated. This unit is sometimes called an oxidation pond. It is a shallow basin, around 3 feet deep, that stores the wastewater in an environment of light, temperature, and oxygen so that aerobic bacteria and algae can reduce the BOD_5 of the influent. Bacteria and oxygen convert the available organic material to carbon dioxide, water, and new cells, thus lowering the BOD. The CO_2 is used by the algae in the presence of light to produce the required oxygen for continuing the conversion. Essentially, the BOD is transferred to the algae. It may be necessary to separate the algae from the effluent of such a lagoon, particularly if the effluent goes to a receiving stream where the oxygen demand would be an adverse factor.

The principal advantage of this treatment method is no odor. The principal disadvantage is the large acreage requirement per animal unit. This lagoon can be designed from data furnished in table 2.

Table 2. Recommendations for lagoon volumes and loadings

Type lagoon	Average volume required (Cu. ft./lb. BOD_5 – day)	BOD_5 loading (lb./acre)
Aerobic (3 ft.)	3700	35
Facultative (5 ft.)	1000	200
Anaerobic (12 ft.)	600	870
Aerated (3 ft.)	900	150
Oxidation ditch (2 ft.)	25	– –

Unit 2. Anaerobic lagoon. The anaerobic lagoon has been used in many applications, both in the treatment of municipal and industrial wastewater and for agricultural wastes. The simplicity of operation is a decided advantage over conventional treatment processes. The land requirement is substantially less than that required for aerobic lagoons.

The more sophisticated anaerobic processes are contained in enclosed units. This allows for positive control of the environment for external heating, for exclusion of oxygen, and for containment of odoriferous gases. Anaerobic lagoons for agriculture do not possess the advantage of a fixed environment.

The bacteria responsible for BOD removal in the anaerobic process live in the absence of oxygen. There are two different types of these bacteria, which combine to bring about anaerobic fermentation. They are the acid-forming bacteria and the methane-producing bacteria.

The acid-forming bacteria take the complex organic matter in the sludge and convert it to simple organic acids, carbon dioxide, and ammonia. Following this, the methane bacteria break down the organic acids and transform them into methane, carbon dioxide, hydrogen, and water. Methane fermentation, the rate limiting reaction, is characterized by:

1. Narrow pH range of 6.8 to 7.2.
2. Temperature in excess of 15°C,
3. Protection of the fermentation zone from oxygen, and
4. High loading rate.

Hence, methane fermentation, which is the essential anaerobic process is highly sensitive to changes in environmental conditions. Chances are that anaerobic lagoons that appear to fail do so because the pH or the temperature exceeded these restrictions.

The principal operating features are the release of methane gas (CH_4), low acreage requirement per animal unit, and some detectable odors. Anaerobic lagoons have greater depths than most (10 to 16 ft.) so as to conserve surface space and so as to provide a low surface to volume ratio. The low ratio gives less heat loss and less oxygen input at the surface. The anaerobic lagoon offers features desired in a primary treatment system for many agricultural waste management situations.

Unit 3. Facultative ponds. This treatment method sometimes arrives unintentionally on the agricultural scene. The term facultative is used to describe BOD reductions by both aerobic and anaerobic bacteria, the former working in the upper liquid areas and the latter occurring in the bottom sludge layers. Depths of 5 or 6 feet and loading rates permitting some settling may well bring about this action. The fate of the organic matter at the pond bottom really depends on conditions at the bottom, i.e., temperature, acid, and loading. Conditions could result in a hydrogen sulfide odor nuisance, or they could bring about methane fermentation and its resulting BOD reduction.

The aerated facultative lagoon has mechanical aeration and some mixing, but not enough mixing to prevent sludge deposits on the lagoon bottom. (A completely-mixed aerated lagoon has all solids in suspension.) Thus the performance is facultative, with methane fermentation along with aerobic digestion; the principal difference in mechanically aerated and natural aeration is that oxygen is mechanically acquired rather than being algae dependent.

These units offer more efficient use of land than aerobic and less odor than the anaerobic lagoons.

Unit 4. Aerated lagoons. One type of aerated lagoon was described under Unit 3. The other type is gained by more intense mixing so as to keep the solids in suspension. In reality, aerated lagoons probably came about to assist in the case where an aerobic lagoon was overloaded and was causing trouble. The aeration increased the capacity to break down BOD and thereby solved the "problem."

The aerated pond or lagoon is a high-rate aerobic treatment unit. The mechanical mixing distributes the oxygen throughout the liquor. With no forced mixing, the oxygen tends to stay close to the surface, especially in winter months. Oxygen transfer could be by algae in summer, but with complete machine-mixing the oxygen is machine-derived, and algae are not apparent.

BOD concentration in the effluent of aerated lagoons, like that in aerobic lagoons, is quite respectable, in the order of 30 p.p.m., whereas in anaerobic lagoons the effluent BOD concentration exceeds 200 p.p.m. and frequently is around 1,000 to 1,500 p.p.m. The aerated lagoons offer low odor levels, reasonable load requirement, and improved effluent concentrations. They are well suited as secondary treatment units as well as for primary treatments.

Unite 5. Oxidation ditch. This treatment method involves the construction of a shallow (around 2 ft.) racetrack-shaped trough with a paddlewheel. It is similar in principle to the mechanically aerated aerobic lagoon in which solids are kept in suspension. The ditch usually requires removal of about 12 to 15 percent of the mixed solids each week. This removal is offset by influent or by adding water to the mixture. The ditch must be properly managed so as to prevent settled solids and anaerobic conditions, which can and usually do initiate foaming and odors.

An oxidation ditch is odorless (assuming no anaerobic conditions are permitted), can be operated indoors or out or both, is reasonable in cost, and requires a minimum of space. The effluent has a high BOD concentration and must be treated prior to release. The effluent can be conveniently handled with sludge traps and a mixed liquor overlow, both feeding into a holding tank or into an aerobic-type holding lagoon.

Blade depths for the paddlewheels of about six inches are common, the oxygenation is normally twice the daily BOD_5 loading, and about 1 kwh. per pound of BOD_5 loading is the normal operating energy requirement. A motor horsepower of one for each 17 pound BOD_5 daily loading is usually selected.

On the basis of operating principles, performance in rural areas, space requirements, and cost there are several possible choices for managing livestock wastes. First, two lagoons can be operated in series. (Example: Anaerobic followed by aerated aerobic.) Second, aerated facultative lagoon followed by oxidation ditch or by sprinkler — irrigation disposal of effluent. Third, anaerobic lagoon followed by modified aerated aerobic unit, then by sprinkler irrigation.

Unite 6. Drying of manure. Another management method too often overlooked is that of handling livestock wastes by removal of moisture rather than by using water in the disposal process. This is especially applicable for poultry manure. Wastes from broiler chicks are now being handled at less than 30 percent moisture in research at Georgia. Wastes under cages are also being dry-processed.

Dehydration of livestock wastes for commercial market disposal is being done on a large scale at the present time. The product is bagged and sold as fertilizer and soil conditioner under many company labels, and the ventures are profitable. Combine this disposal procedure with recycling of wastes as feed supplements, and the quantity of waste required is surprising. Accordingly, drying of wastes for recycling either as feed or as fertilizer must receive much more attention in the future.

Unite 7. Recycling as feed supplement. Feeding of livestock feces is not new, but it is receiving renewed attention because of the emphasis on environmental quality. Catfish have been successfully raised on mixtures of 50 percent recycled manure. Poultry litter is used as a feed supplement in ruminant-feeding programs, and in England the mixture sells for \$28/ton. Feeding of algae is also being evaluated in research trials. The algae is grown with poultry manure.

When manure or effluent from manure lagoons is recycled, either as feed or fertilizer, the spread of disease and antibiotics must be a consideration and must be included in the research studies.

Manurigation

Overhead irrigation is a management tool having sufficient merit to attract considerable attention. When used with an aerobic primary treatment, it should offer an effective way to manage the effluent requirement of the lagoon. It would be still better to pump from an aerated facultative lagoon as a primary unit, and better still from an aerated aerobic lagoon that is in series with a primary lagoon. The latter procedure should be given much more attention in the future.

When applying effluent of a waste treatment system as irrigation water, it is well to provide some means of monitoring the groundwater for possible pollution from nitrates, especially if BOD_5 concentrations in the effluent are high. Some monitoring has been done already, but much more is needed.

Overloaded Lagoons

Many waste ponds were improperly located, constructed, and/or sized. They were built hastily and with as little expense as possible. Many now perform poorly and are little more than holding basins.

These units might possibly be recovered through mechanical aeration. Or they could be used as secondary treatment following a new installation of proper design. In many cases they should be filled in and abandoned.

Pesticides

Pollution of the environment by pesticides is a major problem. In the Southern region especially, the humidity, excess rainfall, longer growing season and type of crops all combine to magnify pesticides as a source of pollution.

Even the containers are improperly managed by many and in themselves represent a pollution source that may require special legislation to correct.

New research emphasis is on nonchemical means of pest control. Even so, there will always be chemicals, new short-persistence ones in most cases, but they offer so much in economy that they are likely to be around for some time to come.

New generators to control droplet size have recently been perfected. This will enhance the use of ultra-low-volume, which in itself is a pollution-limiting feature. In addition, electrostatic spraying techniques are potentially valuable newcomers to this area, but they presently are restricted by inability to properly manage the spray-cloud polarity. When this technique becomes a reality, electrostatic spraying will bring about significant improvements in pesticide application science.

Land Erosion

Much has been done to control erosion. Federal agencies and Experiment Stations have worked more on this pollution source than on any other. The efforts have been underway for years, and a successful action program is very evident.

SCS deserves much credit. They have been working on environmental quality longer than any other group.

Compaction

Increased weight of field machines and tractors, along with heavy traffic over a field for preparation, pesticides, and harvest have intensified the problem of soil compaction. This soil condition is a pollution source because it lowers yields, increases runoff and violates improvements in economy and efficiency in other aspects of agricultural production.

Subsoiling is a partial answer and is a benefit.

Fixed wheel tracks for the power units, even paved tracks, offer additional alternatives. It is quite likely that high intensity crops of the future will employ a fixed track for field-machinery operations.

Processing Wastes

A reduction in pollution sources will occur when improved grading and handling procedures are developed for such crops as peaches and vegetables, and when more of the debris is left on the production site rather than being transported and abandoned at the processing plants. The trash in vegetables and the bark of wood pump are examples.

Sawdust in lumber mills, peanut hulls, pecan hulls, and peach peelings are examples of wastes at the processing plant. These materials might be recycled as ingredients of other compositions, or as feed. They may also be recycled as fuel, especially is this true of peanut hulls which are being used to manufacture peanut-hull-charcoal.

Additional uses and products for recycling require continuing research.

The waste-treatment lagoons previously described can be used to handle biological processing wastes such as peelings and especially the byproducts from rendering plants.

The rendering plant is in itself an exceptionally important example of recycling processing wastes. Without these plants the poultry, broiler, and catfish-processing plants would be in serious trouble. Slaughtering plants also come in the same category. Interestingly enough, the byproducts from byproducts are also great sources of pollution. In particular, there is the wastewater and the odors as byproducts which must be managed, otherwise the rendering plants are in trouble. At the present time, serated ponds in series are helping with the wastewaters, and research grants are under consideration at the moment which, if approved, will initiate odor-abatement studies at poultry-rendering plants.

Concluding Recommendations

There is no longer a question of whether to control or eliminate a source of pollution but rather a question of which is the best way. The level of control is, at the moment, flexible, and in the best interest of all will remain so. Some pollution sources can be eliminated, some can be at best confined to acceptable limits. The principal procedure is to move out with the best information at hand, seek understanding, co-operate, and take action in good faith.

Education is vital. The agriculturist must be informed of the consequences of mismanagement of animal wastes, pesticides, land, crop residues, and exhaust air. The individuals or agencies at the local and State level must be thoroughly informed of the technical, social, and economic aspects of the pollution area in which they are to judge and evaluate. Consideration of the social costs and the social benefits, along with good judgment and wise counsel on the interaction of actions, is more necessary right now than at any prior time.

ANIMAL WASTE — DISPOSAL OR UTILIZATION

by

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Research directed specifically toward animal waste management has been in progress for about 4 years at North Carolina State University. Recently, the anticipated laboratory for agricultural-waste management studies has become a reality. The new and well-equipped laboratory in the Department of Biological and Agricultural Engineering and the complementary university research farms provide excellent facilities for ongoing and proposed agricultural waste research programs in North Carolina.

Early research on animal waste in the Department of Biological and Agricultural Engineering was conducted under a Federal Water Pollution Control Administration (FWPCA) Environmental Protective Agency (EPA) grant. This 2-year project, "Role of Animal Wastes in Agricultural Land Runoff", investigated the actual and potential importance of animal wastes in respect to water quality management. Runoff from agricultural land had been alleged to exert an important influence on environmental quality. However, at the time of this research, little factual information had been produced concerning the nature and extent of the problem. The many generalizations made about agricultural wastes and corresponding pollutional potential were to a large extent dependent upon inference, supported at best by very limited field studies.

While this study was principally concerned with runoff from land disposal, attention was directed to animal waste lagoons because of the interest in this disposal method. There were over 2400 swine waste lagoons in just North Carolina during 1968. Another factor has been that the Soil Conservation Service (SCS) through Agricultural Stabilization and Conservation Service (ASCS) is providing financial assistance for the construction of animal waste lagoons.

The following is just a gleaning of the published results of this project[1,2,3]. Data for unaerated swine waste lagoons showed that the pollutional potential of lagoon effluent was considerably stronger than that of raw domestic sewage. The rate of loading on these studied lagoons was about one-tenth the level prescribed by the SCS specifications[4]. These findings indicate that unaerated lagoons are not satisfactory as a sole means of treatment of animal waste and that the discharge of such effluents is not acceptable from a water quality standpoint.

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[1] Robbins, J. W. D. Water pollution by swine production operations. Unpublished Ph.D. thesis, Department of Biological and Agricultural Engineering, North Carolina State University at Raleigh. University Microfilm, Ann Arbor, Mich. 1970.

[2] Robbins, J. W. D., Kriz, G. J., and Howells, D. H. Quality of effluent from swine production areas. ASAE Paper No. 69-706. 1969.

[3] Robbins, J. W., Howells, D. H., and Kriz, G. J. Animal wastes in agricultural land runoff. Proceedings 20th Southern Water Resources and Pollution Control Conference, Chapel Hill, N.C. 1971.

[4] Soil Conservation Service, Interim Specifications — Disposal Lagoons, Advisory Eng-5, USDA, Washington, D.C., Jan. 28, 1970.

Although many animal waste lagoons are designed and considered as non-overflow installations, most lagoons in the Southwest eventually operate as overflowing units. The amount of water input to lagoons is greater than the evaporative losses because in North Carolina the average annual rainfall is 45 to 50 inches and the corresponding evaporation is only about 30 inches. Lagoons will generally seal over a period of time, but the extent to which this will occur is ill-defined. As lagoon leakage is reduced it becomes necessary to dispose of the excess water or continuously release overflow effluent. Therefore, it was recommended that the effluent from unaerated lagoons be applied to the land by irrigation or some other acceptable means[2].

Results from the land disposal portion of the study showed that the quality of receiving waters varied inversely with rainfall and runoff. That is, the magnitude of pollutional parameters increased with the amount of streamflow. The only exception was in the case of watersheds where nitrate has penetrated into the groundwater. Nitrate pollution of groundwater was indicated if the nitrate concentration was highest during base flow in a watershed where groundwater was the source of flow, and then decreased to a very low level during periods of runoff or dilution. The highest levels of pollution (biochemical oxygen demand (BOD), nitrogen, phosphorus, etc.) experienced during periods of peak flow were less than 10 percent of the corresponding parameter concentrations in unaerated lagoon effluents and very little higher than the pollutants rising from the control watershed which housed no domestic animals. The relatively high level of pollutants from the "pollution free" watershed, arising from decaying vegetation and wildlife during a rainfall-runoff event, was surprising.

These results show that land spreading of animal wastes under proper conditions is far superior to lagooning. The quality of receiving streams is largely unaffected by land spreading during periods of no rainfall, and there is very little pollution in excess of that from natural runoff during periods of rainfall. However, even with land disposal, good management practices of soil and water conservation are essential in selecting disposal areas and choosing deposition times to minimize movement of wastes to streams. Also, the amount of wastes applied per unit area should be regulated to prevent excessive nitrate penetration into the groundwater. While there are problems associated with land disposal, such as land location and availability, labor, odor, and fly control, land spreading is an ecomomic and effective method of animal waste disposal.

Severe problems with the BOD analysis of swine waste were experienced during the entire period of the FWPCA (EPA) study. The standard BOD_5 value consistently varied with the amount of sample dilution. This BOD value variation was attributed to the possible inhibitory effect of feed additives such as antibiotics, copper, and other toxic metals.

A following research project, "Exploratory Study of Limitations of BOD for Animal Waste Evaluation", supported by the Water Resources Research Institute of the University of North Carolina, focused upon the suitability of the BOD test for the evaluation of agricultural wastes and investigated the effect of feed additive carryover on the BOD analysis. This research was considered as more significant than a mere analytical exercise, because concern existed about the reliability of the BOD test as the mainstay of pollution-control technology and as a basis for public investment in environmental quality. Although the BOD test outlined in Standard Methods for the Examination of Water and Wastewater[5] has been the most widely used analysis by Sanitary Engineers for the measurement of organic pollution in terms of the oxygen required for the biological stabilization of wastewater, problems with the BOD test have been reported periodically by workers investigating municipal and industrial wastewater for about 50 years. Therefore, it is not unusual that many researchers in the field of agricultural waste management have been seriously plagued by the difficulty of obtaining reproducible BOD data even though the procedures outlined in Standard Methods have been rigorously followed.

Special attention was given to sample preparation during this study on the BOD test, because of the very high solids and chemical contents of animal waste. The abundance of large-sized particulate matter made it very difficult to obtain a representative sample. Additionally, the waste sample had to be extensively diluted so that the concentrations of the parameters tested were within the determination limits for the analytical procedures set forth in Standard Methods. All BOD dilutions were made in volumetric flasks and transferred to BOD bottles by siphoning to insure uniformity of sample concentrations in triplicate bottles. BOD determinations were made on unseeded samples incubated for five days at 20° C.

The BOD_5 results for the solid feces, lagoon influent, and lagoon effluent showed similar variations in the magnitude of the BOD5 value with sample concentration. Typical curves illustrating this BOD5 data variation are shown in figure 1, with the magnitude of the BOD5 value plotted on the ordinate versus percent sample concentration on the abscissa for each waste. Such curves are representative of wastes containing toxic or inhibitory substances, because the BOD5 value decreases as the amount of sample and, consequently, amount of inhibitory substances, increases in the bioassay bottle. No variation in the BOD5 value with sample dilution should occur if dilution and/or analytical errors are avoided and inhibitory substances are not present.

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[5] Standard Methods for the Examination of Water and Wastewater, Twelfth Edition, American Public Health Association, Inc., New York, 1965.

Domestic sewage was used to determine the minimal inhibitory concentration (MIC) of copper, zinc, and chlortetracycline that would affect the standard BOD5 analysis. Typical curves showing the individual effect of copper, zinc, and chlortetracycline concentrations on the BOD5 analysis of sewage are shown in figure 2. Results verified work by Placak and coworkers[6] that about 0.01 mg./1. of copper affects the BOD5 results for sewage. The MIC for copper was in the range of typical copper concentrations present in the bioassy bottle for the BOD analysis of swine waste, whereas the average zinc and chlortetracycline concentrations in the BOD bottle were below the indicated MIC.

The total effect of copper, zinc, and chlortetracycline on the BOD5 analysis was studied, employing the same ratios that were present in the waste. The MIC for the total combined effect of the inhibitory substances on the BOD analysis of domestic sewage was approximately 0.012 mg./1. as shown in the typical curve presented in figure 3. For the combined amount of inhibitory substances, the copper portion was 0.065 mg./1, the zinc concentration was 0.043 mg./1, and the chlortetracycline content was 0.0012 mg./1. The amount of copper present in the total-effect analysis was similar to the recorded MIC for just copper. These results indicate that copper was the controlling inhibitory substance affecting the BOD analysis of swine waste.

Since it was recognized that the MIC for copper was about 0.01 mg./1., BOD5 sample concentrations were chosen so that the copper concentration was less than about 0.01 mg./1. BOD data for sample concentrations containing less than the MIC of copper showed an oxygen depletion of only about 2 mg./1. or less. In contrast to published recommendations for the selection of the most reliable BOD results, that the acceptable sample with the greatest oxygen depletion is statistically the best, the results of this study showed the BOD5 data for swine wastes can be considered reliable only when a compromise is made to obtain a sufficiently dilute sample so that the copper concentration is below 0.01 mg./1 and the resulting oxygen depletion is as large as possible (preferably greater than 2 mg./1.

This study illuminates a dilemma that exists between the criteria set out in Standard Methods for the Examination of Water and Wastewater and the requirements for the accurate evaluation of agricultural wastewater. Standard Methods specifies that an oxygen depletion of at least 2 mg./1 should be considered the most reliable. However, regardless of the amount of oxygen depletion, reliable BOD data cannot be obtained if the sample concentration is such that inhibitory amounts of copper or other feed additives exist.

Data show that a direct relationship exists between the amount of organics or oxygen demand and the concentration of copper for series dilutions. Thus, it may be impossible to obtain a copper content below the MIC and still realize more than a 2 mg./1 oxygen depletion. For such wastes, a compromise must be made to select a sample dilution that has the lowest possible concentration of inhibitory substances, but a sufficient amount of organics to provide a technically acceptable oxygen depletion. BOD values for sample dilutions resulting in only 1 to 2 mg./1 oxygen depletion may be more reliable than data for samples with more than a 2 mg./1 oxygen depletion, if any MIC value is exceeded in the more concentrated samples. Every effort must be made to select a sample dilution that results in the greatest oxygen depletion but yet approaches or is below the MIC for any material.

The routinely employed analyses outlined in Standard Methods for the characterization of sewage or municipal wastewater cannot be indiscriminately used for the characterization of agricultural wastes. These standard tests, which were developed to evaluate a dilute and homogenous wastewater such as sewage, are generally not completely suitable or sufficiently sensitive to accurately characterize the pollutional potential of more concentrated agricultural wastes.

Municipal sewage is composed of large quantities of water contaminated with relatively small quantities of wastes whereas agricultural wastewaters generally consist of high concentrations of organics diluted with small amounts of water. Therefore, for agricultural wastes,

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[6] Placak, O. R., Ruchhoft, C. C., and Snapp, R. G. Copper and chromate ions in sewage dilutions, effect on BOD. Indus. Engr. Chem. 41: 2238-2241. 1949.

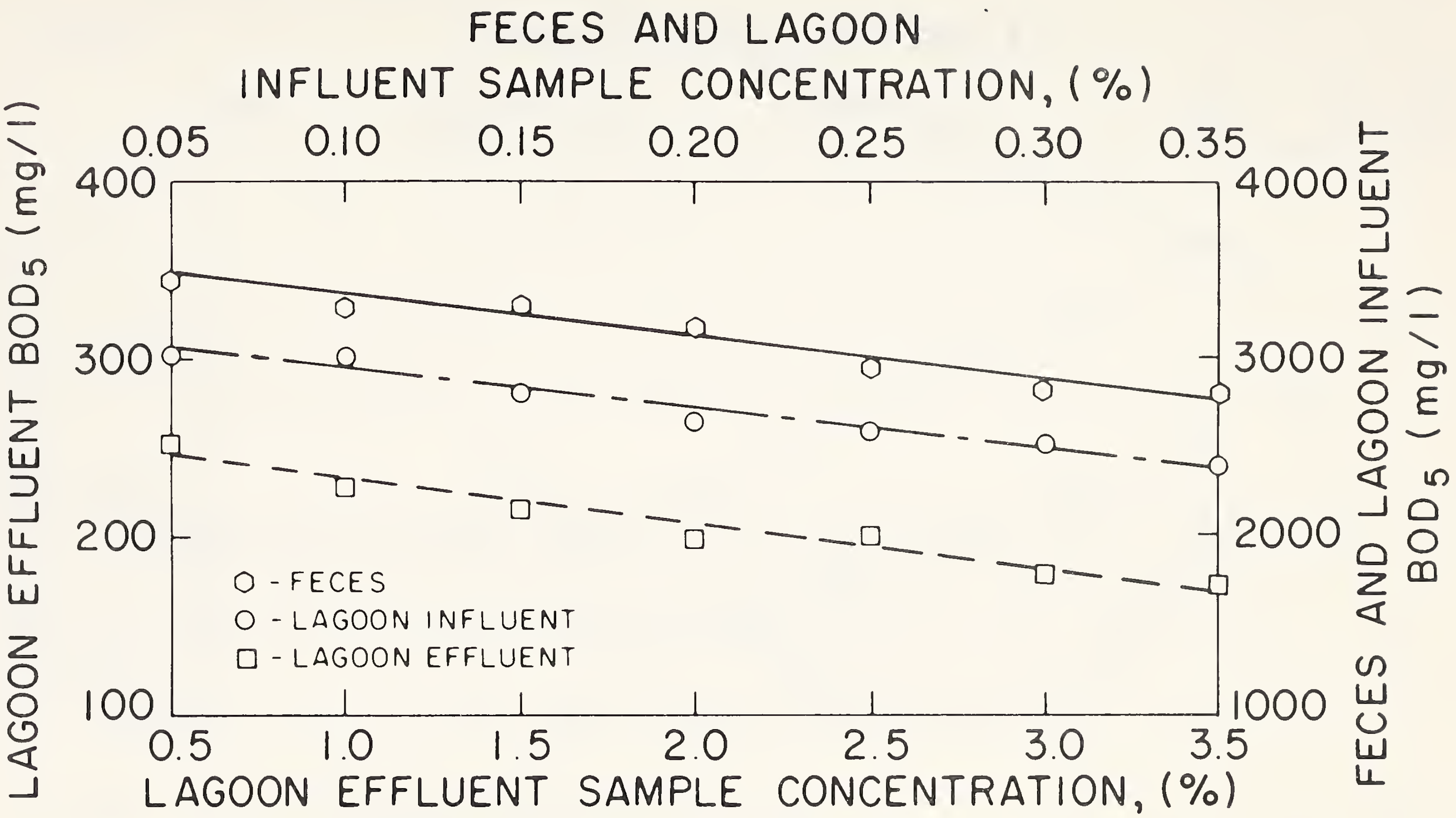

Figure 1. Typical BOD_5 values versus percent sample concentration

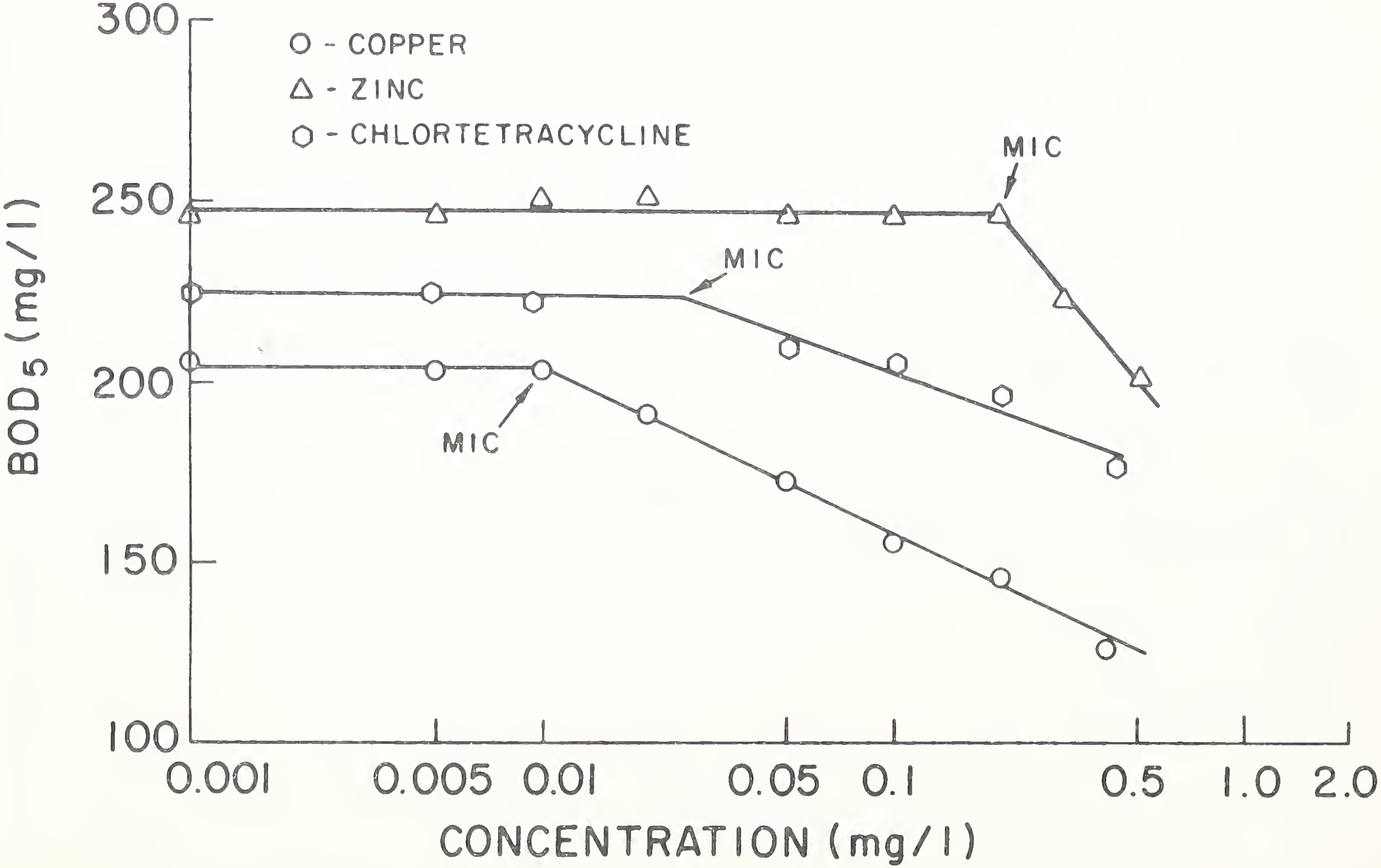

Figure 2. Typical effect of individual feed additives on the BOD_5 analysis of domestic sewage

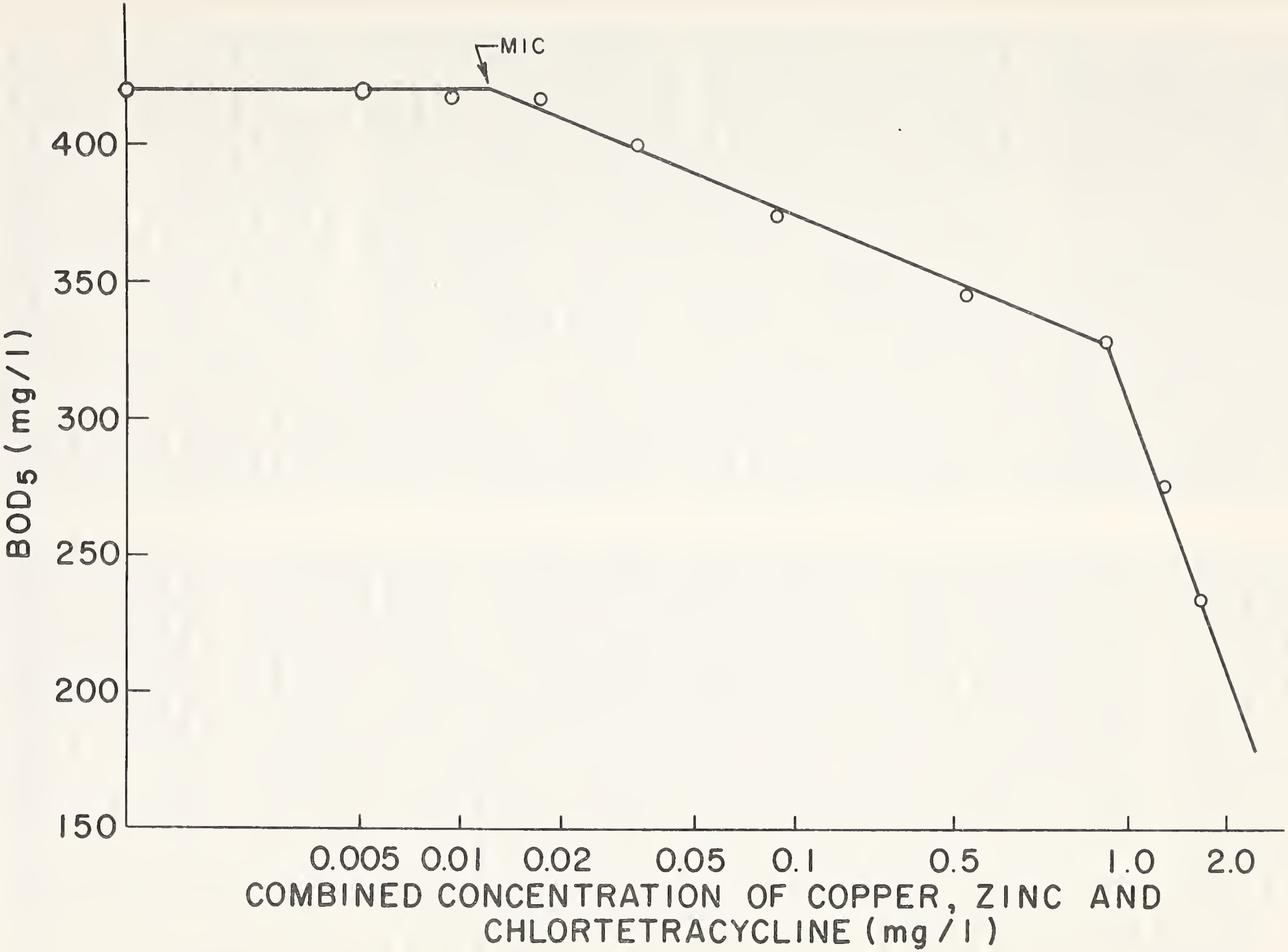

Figure 3. Typical total effect of copper, zinc and chlortetracycline on the BOD_5 analysis of domestic sewage

particular attention must be directed toward obtaining a homogeneous and representative sample for testing. Waste solids must be broken down and the sample made as homogeneous as possible if meaningful results are to be obtained. This is particularly important for the instrumental analyses, since the small orifice of the sample syringe will restrict the passage of particulate material, and the results will be correspondingly prejudiced.

Analytical technique and procedures for many of the standard analyses for domestic wastewaters may have to be modified, and other tests may not be applicable for agricultural wastes because reproducible results and accurate data cannot be obtained for these wastewaters. The variation of the BOD value with amount of sample dilution for animal waste is an example of a problem consistently experienced with a standard test, which may eventually negate the applicability of this test for animal waste or at least evoke procedural modifications.

Ideally Standard Methods should be modified and/or augmented to include provison for the equitable evaluation of agricultural wastes. Many tests in Standard Methods are appropriate for the evaluation of animal waste, as demonstrated by some bacterial examinations. It was found that for both sewage and swine waste, the membrane-filter technique outlined in Standard Methods for the determination of fecal streptococcus densities was superior to the membrane-filter method suggested by Millipore Corp. However, as indicated by the BOD data, other tests may not be appropriate or valid, and thus specific attention must be directed to the limitations of these analyses and corresponding procedural or analytical modifications required for the accurate characterization of agricultural production and processing wastes.

The dilemma of obtaining technically sound oxygen-demand or pollutional potential data for agricultural waste may be mitigated by directing more attention to the chemical oxygen demand (COD) test and appropriate instrumental analyses. Although the results obtained for the COD test and oxygen-based instrumental analyses are higher than corresponding BOD data, these values may be more representative of the ultimate oxygen demand any waste will have on the environment.

The COD test measures the amount of oxygen required for the chemical oxidation of waste to carbon dioxide and water. The laboratory procedure involves a 2-hour digestion with strong oxidizing agents. The COD value is generally larger than the corresponding BOD value, because many materials that are chemically oxidizable cannot be metabolized or oxidized by the microorganisms during the standard 5-day period for the BOD test. However, if the waste remains relatively uniform or characteristic, a good correlation between COD and BOD results can be established.

The carbon or organic level of wastewater has also been considered as an important measure of pollutional potential, but the analytical methods have been arduous and time-consuming. BOD data often has been interpreted in terms of organic matter, because a relationship exists between the amount of oxygen utilized by the microorganisms and the amount of organics metabolized. The total organic carbon (TOC) analyzer now allows a rapid and simple means of determining carbon levels in wastewater samples and correspondingly has enhanced the popularity of organic carbon as a measure of pollutional potential.

The effective application of both oxygen- and carbon-based parameters is the most logical basis for evaluating pollutional potential. COD provides an excellent measure of oxygen demand, since it is a 3-hour chemical or 2-minute instrumental analysis that is not influenced by the variables that affect bioassays such as the BOD test. The Precision Aquarator instrumental analysis for COD, referred to as CO_2D, gives good correlation with the standard COD test. The conjunctive use of instrumental oxygen-based and carbon-based analysis would allow the most rapid, reliable, and technically sound method of determining the pollutional potential and oxidation state of wastewater.

Although accurate waste characterization is necessary, today's most pressing problem is the satisfactory treatment and disposal of waste. Because the large number of existing lagoons represent a substantial investment and provide a degree of treatment, it seems reasonable to direct efforts to allow their continued utilization either by upgrading lagoon effectiveness or developing additional unit processes to assure adequate final treatment of animal waste. Current investigations at North Carolina State University are studying land application of unaerated lagoon effluent, series lagoons with and without land application of effluent, and aerated lagoons.

Irrigation is an attractive method of additional or finishing treatment of effluent from animal waste lagoons, since soil systems have proved to be effective for tertiary treatment of sewage. Classically the return of waste residues to the land has been the natural practice of farmers. When land availability and location allow, lagoon effluent should be viewed as a valuable resource that could be used for irrigation and waste nutrient reclamation. However, irrigation is not applicable for all livestock producers, and therefore other methods for final treatment of lagoon effluent and disposal of animal waste that are feasible and adequate must be investigated. Lagoon aeration may not seem unreasonable when aeration equipment and operating costs are compared with land and labor requirements for series units and land application. As current research findings become available, reliable technical guidelines and design criteria applicable to the Southeast will be developed. Such information would illustrate the relative feasibility of various treatment methods, so that the decisions for treatment-system selection could be based upon valid engineering and economic criteria.

Unfortunately, contemporary emphasis seems to be directed toward destructive methods of waste treatment and disposal. Long-range goals must consider methods of nondestructive waste utilization and recycling of waste nutrients. Land application of manures or irrigation of lagoon effluents allows reclamation of waste fertilizer nutrients and utilization of potentially pollutional wastewater as an irrigation resource. The product resulting from the compositing of poultry waste and sawdust, as well as dehydrated manures, provides an excellent soil conditioner. These waste resources can be utilized to help grow the required forage for livestock production or even other valuable crops. Such waste-management systems would not only recycle potentially pollutional wastes into the environment, but would also implement effective waste-nutrient conservation and conversion to useful products.

More effective systems for nondestructive waste-nutrient conservation, conversion, and utilization must be developed. Morally we have this obligation, because we in the U.S. represent only about 6 percent of the world's population; yet we use over 60 percent of the earth's minerals consumed annually. All meat producers who are to remain competitive food suppliers are charged with this responsibility. Although no synthetic food or meat substitute has the appeal of a freshly fried egg, roasted turkey, or T-bone steak, synthetic foods are acceptable, and they may be more economical due to the reduced environmental burden associated with their production.

The message is crystal clear. Meat producers and processors must avoid the anal attitude and upgrade efficiency by judiciously reducing system exhaust. Many will feel that the cost of waste treatment is prohibitive, and for those it will be a deterrent that may possibly preclude their future operation. Waste must be viewed as a potential asset rather than as a liability to the entire industry and environment. Waste management has to be considered as an integral part of the total system and given as much attention as raw materials, operational procedures, and product quality.

Progressive waste utilization alternatives include the processing and recycling of manures as animal feed. This is significant, because animals are not very efficient in extracting feed nutrients, and therefore their waste contains large amounts of unconsumed food and energy, which consequently poses a high pollutional load on the environment. Successful research on the refeeding of animal manures has been conducted. Incidently, in one of these studies[7], the 12th-rib steak from beef cattle fed hydrolyzed poultry waste was given the highest rating by a taste panel. Are we ready to eat this steak? However, the bigger question may involve the long-term safety of this steak! Problems experienced with grass tetany, fat necrosis, and animal acceptance must be compounded with potential long-range health hazards that may result from the direct refeeding of animal manures. Public acceptance will also be a major consideration. Problems associated with the direct utilization of animal manures can be eliminated or at least mitigated by biological or physical transformation of these waste nutrients into a safe and acceptable food or feed additive.

Caution seems to be the most important word and directing concept for the recycling of animal manures. We must continually consider and elucidate possible deleterious effects or potential long-range hazards. Possibly integrated livestock production units will develop, so that poultry excreta can be refed to ruminants and then ruminant waste ultimately returned to the land so as to be utilized for the production of required forage. Certainly the implementation of waste utilization will make livestock production more efficient and economical.

The public is demanding increased environmental quality and if they are not to be hypocrites they must be willing to accept reasonable costs. Prudent agricultural personnel are sympathetic with these demands and desire to implement methods that ameliorate environmental pollution. Such agricultrual producers and processors will view waste as a potential asset and constantly seek treatment methods that provide reinbursement so that waste-management expenses must not be completely assimilated by increased product cost.

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[7] Long, T. A., Bratzler, J. W., and Frear, D. K. H. The value of hydrolyzed and dried poultry waste as a feed for ruminant animals. Cornell University Conference on Agricultural Waste Management, Syracuse, N.Y. 1969.

POLLUTION PROBLEMS RELATED TO PESTICIDE CONTAINERS[1]

by
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INTRODUCTION

There is a growing awareness of the pollution of our environment by pesticides and pesticide containers. This awareness has focused attention on some old practices that contribute to the pollution. These old practices are basically the ones that require the manipulation of our environment in order to produce an adequate supply of food, feed, and fiber. But to be successful in the production of life's necessities, we must combat various pests that attack us, our crops, and our livestock.

The protection of ourselves, our livestock, and our food crops against damage by disease, nematodes, insects, and weeds involves the use, among other measures, of effective chemical methods of control, that is, the use of pesticides. In fact, in recent years pesticides have become an integral part of our lives and are considered essential tools for safeguarding our environment from the ravages of pests.

Pesticides are generally safe and effective when properly used. In many instances, they are the only means for controlling pests. Until there is a major breakthrough in the development of alterative methods for controlling pests, such as biological methods (that is, the use of multiple pest-resistant high-yielding varieties of crops, sound crop rotation, and field sanitation), pesticides must continue to be used as tools in agricultural production.

In the past, the use of pesticides for agricultural purposes has not been responsible for most of the spectacular cases of environmental pollution. However, the potential for pollution has been intensified in recent years due to increased usage of pesticides in agriculture. The case in point is that the use of pesticides has accounted for at least 20 percent of the increase in farm output since 1940[2]. For example, in 1966 farmers used about 353 million pounds of pesticides (active ingredients)[3] valued at approximately $400 million. This quantity of pesticides accounted for 51 percent of the total domestic use[4]. There are presently more than 100 firms producing about 1,000 pesticide chemicals, which are formulated into about 50,000 commercial pesticide products[3]. In 1970, about one billion pounds of pesticides (active ingredients) were sold at an estimated retail value of $2.0 billion[2]. Projections to the year 1975 indicate that the anticipated sales of pesticides will reach $3.0 billion[5].

These few statistics illustrate the magnitude and trends in the use of pesticides in farming. They reemphasize that the use of pesticides by farmers has played an important role in the vast increase in farm production. In other words, pesticides, when used judiciously, have resulted in benefits to man and his environment. But, like most innovations, the use of pesticides has created new problems, particularly through misuse or careless use. Today we are not only confronted with possible pollution of the environment by pesticides from the normal widespread — sometimes indiscriminate — usage but also by "empty" pesticide containers. It follows then that, in addition to the potential hazards associated with the use of pesticides, there is the problem of decontamination and disposal of pesticide containers. The development of effective, safe, economical, and practical procedures for the disposal of unused pesticides, pesticide wastes, and pesticide containers has not, however, kept pace with progress in the development and use of pesticides. Therefore, the development of safe methods for disposal of unused and waste pesticides and "empty" pesticide containers is just as important, if not more important, than the development of methods for the safe use of pesticides. There is no longer an "away" into which empty containers can be dumped. Disposal of this kind of waste by "throwaway" methods may not only create unsightly surroundings and public nuisances but may also create unsafe loci at the deposit sites, as many so-called "empty" containers carry substantial amounts of leftover pesticide materials. Using land and surface waters (lakes, rivers, streams, etc.) as "catchalls" into which pesticide containers are discharged is prohibitive on the grounds that chances for environmental pollution are very great.

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[1] This study was supported by Agricultural Research Service, U. S. Department of Agriculture Grant No. 12-14-100-9182(34), administered by the Plant Science Research Division, Beltsville, Md.

[2] Shaw, W. C. How agricultural chemicals contribute to our current food supplies. Presented at symposium "Agricultural Chemicals — Harmony or Discord for Food, People, and the Environment," February 16 and 17, 1971, University of California, Sacramento.

[3] Davis, Velmar W. Farmer's use of pesticides and pesticide containers. In Proceedings National Working Conference on Pesticide Disposal, June 30 and July 1, 1970, pp. 39-53. National Agricultural Library, Beltsville, Md.

[4] U. S. Department of Health, Education, and Welfare. Report of the Secretary's commission on pesticides and their relationship to environmental health. U.S. Government Printing Office, Washington, 1969.

[5] Shaw, W. C. Recent advances in research on the disposal of pesticide wastes and pesticide containers. Presented at 57th Annual Meeting, Chemical Specialties Manufacturers Association, Inc., December 13 to 16, 1970. New York.

We, who are associated with agriculture, must be sincerely concerned with preventing pollution of our environment by pesticide containers. In this regard, the Mississippi Agricultural and Forestry Experiment Station, under a grant from the USDA, is studying the problem of safe disposal of pesticides and containers with the overall objective of reducing pollution of the environment. The research is being conducted jointly by the Departments of Agronomy—Soil Science, Agricultural and Biological Engineering, and Biochemistry of the Experiment Station. The remainder of this presentation will be concerned with the nature and magnitude of the pesticide-container problem, some approaches to its solution, and a brief review of certain research findings in this area.

THE NATURE AND MAGNITUDE OF THE CONTAINER PROBLEM

It has already been implied that, in regard to pesticide chemicals, the major problem confronting the nation, and specifically the South, today is the handling and disposal of "empty" pesticide containers without polluting the environment. While the surplus chemicals are generally stored in their original containers, the "empty" containers remaining after agricultural and household usage are strewn over the countryside. Removal of these pesticide containers from the environment is not only in the interest of safety but also in keeping with the improvement of the esthetic appearance of the landscape.

The magnitude of the container problem can best be appreciated by consideration of the number of pesticide containers presently used both in the whole United States and locally in Mississippi.

An estimated 130 million containers are used nationally for agricultural pesticides. In addition, approximately 100 million aerosols supply pesticides for household uses[5]. Containers are used for packaging formulated pesticides as liquids, dry materials, and aerosols. They range in sizes from less than one ounce to 55-gallon drums and are made of a wide spectrum of materials such as metal, glass, fiber, paper, plastic, etc. It is currently estimated that approximately $31 million is spent each year to dispose of unused pesticides and containers. This figure amounts to approximately 15 percent of the annual pesticide sales[5].

To focus on the magnitude of the container problem closer to home, let us use as an example the State of Mississippi, one of several States which is regarded as a high pesticide-use area. In 1968 and 1969 the Mississippi Cooperative Extension Service conducted surveys of the number of pesticide containers (excluding paper containers) used in Mississippi[6].

The results of the surveys, which are presented in table 1, indicated that the rate of increase in the number of containers in the span of one year was 20.4 percent. It is noted that 5-gallon cans and 1-gallon containers (metal, glass, and plastic) accounted for two-thirds of the total number of purchased containers. However, the greatest increase was among the 55-gallon metal containers.

The large volume of pesticide containers in circulation both on the national and local levels clearly indicates that the container problem is growing by leaps and bounds. Moreover, the problem associated with pesticide containers is expected to continue to increase paralleling the growth of population which, in turn, will cause an increase in food requirements and thus create a greater demand for pesticides.

SOME APPROACHES TO THE SOLUTION OF THE CONTAINER PROBLEM

The container problem might appear small when one considers a few containers on an individual operation, but it is greatly magnified when one looks at the number of containers on a large scale. With the growing concern over pollution of all kinds, agriculture will be faced with the tremendous problem, in the not too

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[6] Bennett, A. G., Mississippi Cooperative Extension Service, Personal Communication.

Table 1. Estimated number of containers purchased in Mississippi in 1968 and 1969 by size and type of container[1]

Container		1968		1969		
Size	Type	Purchased	Percent of total	Purchased	Percent of total	Percent increase
55 Gallon	Metal	46,500	6.7	65,750	7.8	41.4
30 Gallon	Metal	13,500	2.0	16,000	1.9	18.5
5 Gallon	Metal	185,000	26.6	240,000	28.7	29.7
1 Gallon	Glass	1,000	0.1	1,000	0.1	0.0
1 Gallon	Metal	175,000	25.1	200,000	23.9	14.3
1 Gallon	Plastic	175,000	25.1	200,000	23.9	14.3
1/2 Gallon	Plastic	30,000	4.3	35,000	4.2	16.7
1 Quart	Metal	70,000	10.1	80,000	9.5	14.3
TOTAL		696,000	100.0	837,750	100.00	20.4

[1] Mississippi Cooperative Extension Service; no record made of paper containers.

distant future, of container disposal.

In the disposal of pesticide containers, the sins of the farmer and the commercial applicator are numerous. One needs only to drive on a rural road in almost any area of the country, and along the roadside he will see empty pesticide containers dropped beside the woods, discarded in the fields, floating in streams, ditches, and ponds, or lying beside the road.

Regardless of the reasons why containers are being discarded on the beautiful landscape, their presence in our environment creates very real threats to human and animal life. Even so, disposed of they must be!

There are several makeshift procedures for disposal of containers. Table 2 summarizes several of the procedures used. It should be emphasized that these are not necessarily recommended procedures, but rather are those which are practiced by farmers, aerial applicators, formulators, and others. The table was complied from government and private publications and from personal observations by the authors. It follows from this summary of disposal methods that at the present time, burning in the open air, burial in dumps, or a combination of the two are the most commonly employed procedures.

Table 2. Presently used methods for the disposal of empty pesticide containers[1]

Type and size of container	Method of disposal
Large — metal (chiefly 30- and 55-gallon)	Washing and reusing Washing and destroying Burning, reconditioning, and reusing Burning and destroying Burning after mutilation at dump Returning to supplier Selling to a cooperate firm
Small — metal, glass, etc. (chiefly 5-gallon or less)	Crushing or breaking and burial in dump Burning and burying in dump
Paper, plastic, etc.	Burning and burying ashes Burying in dump

[1] Compiled from government and private publications and from personal observations of the authors.

In view of the diversity of disposal methods, in 1967 a direct mail survey to obtain information about the disposal of empty pesticide containers was conducted by the authors in Mississippi. In this survey, an appropriate questionnaire was sent to farmers in selected counties. The recipients of the questionnaire were cotton farmers who had cotton acreage allotments of 100 acres or more (as determined from current ASCS. records for the given county). The results (table 3) indicated that various containers were disposed of by farmers in the following ways: burned, 43.8 percent; dumped (city and farm dumps, gully, bayou, etc.), 26.8 percent; sold, 9.3 percent; stored, 7.1 percent; and other miscellaneous procedures such as reusing, returning to the dealer, burying, etc., 13.0 percent.

Table 3. Methods of disposal of pesticide containers by Mississippi farmers[1]

Disposal method	Number of containers[2]	Percent
Stored	1,760	7.1
Reused	949	3.8
Trash containers	371	1.5
Spray applicators	12	0.1
Culverts	80	0.3
Shop use	199	0.8
Water trough	8	0.1
Sold	1,308	9.3
Returned to dealer	431	1.7
Burned	10,878	43.8
Buried	1,197	4.8
City dump	2,478	9.9
Gully	181	0.7
Farm dump	2,696	10.8
Left at aerial applicators	296	1.2
Bayou	1,017	4.1
TOTAL	24,861	100.0

[1] Direct mail survey.

[2] Includes metal, glass, fiber, paper, plastic, etc.

From this study one can calculate that the surveyed farmers disposed of approximately 75 percent of their pesticide containers chiefly by three methods: burning, burying, or dumping. Regardless of which disposal procedure is used, there is a great danger that containers may enhance the formation of poisonous parameters in the soil at the disposal sites because of the accumulation of high concentrations of waste pesticides.

A study conducted in Canada[7] revealed that substantial amounts of liquid-formulated pesticides remained in the containers after normal emptying. For example, an average of 2.7 percent of the pesticides remained in the 5-gallon round cans with pouring spout and air vent punch, while averages of 2.2 and 2.8 percent of the original contents were recovered from one-gallon and half-gallon rectangular containers. If, on the basis of this study, one assumes that "empty" pesticide containers carry an average residue of 2.5 percent of the original contents, and if one further assumes that all of the pesticide containers purchased in 1968 and 1969 (table 1) in Mississippi were disposed of, the quantity of pesticides disposed of with the containers would have amounted to approximately 100,000 gallons in 1968 and 143,000 gallons in 1969. In other words, the amount of pesticide which could have been added to the disposal sites with these containers had increased 44 percent in the span of a year.

Not only are the present disposal procedures unacceptable with regard to environmental pollution, but they are also quite costly. Using the information from the Mississippi surveys of purchased containers (table 1) and methods of container disposal (table 3), we can estimate the labor cost involved in disposal. Let us assume that one hour is required for handling and ultimately disposing of every two 55- or 30-gallon drums, every four 5-gallon pails, and every 10 small (1-gallon or less) containers[8]. On this basis, the time required to dispose of pesticide containers by burning, burying, or dumping (75 percent of the total containers) was estimated to be 91,000 hours in 1968 and 114,000 hours in 1969. If we also assume that the cost of labor was $1.50 per hour, then the cost of disposal by these three methods was $137,000 in 1968 and $172,000 in 1969. These figures, which represent a 25.6 percent increase in time and labor during one year, do not include the cost of operating any mechanical equipment used in the disposal procedure.

Disposal by burning is considered to be the best available means for solving the pollution problem caused by pesticide containers. However, the common practice of burning in the open air is objectionable for at least two reasons. Firstly, the toxic and corrosive gases (such as carbon monoxide, sulfur oxides, nitrogen oxides, ammonia, or halogens) and the particulate matter which may be emitted during incineration of the containers and the pesticide residues remaining in them are released directly into the atmosphere. Secondly, toxic materials such as arsenic, zinc, or mercury may remain in the ash.

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[7] Cooper, G. S., Cyanamid of Canada, Ltd., Personal Communication.

[8] Jansen, L. L., Estimates of container numbers by size, type and formulations involved. In Proceedings National Working Conference on Pesticide Disposal, June 30 and July 1, 1970, pp. 27-38. National Agricultural Library, Beltsville, Md.

Notwithstanding these objections, a well-designed incineration system equipped with devices to entrain the noxious gases and the particulate matter in the effluent air stream appears to be the best means for disposing of pesticide containers. With this final aim in view, research at Mississippi State University has been concerned with determination of the burning characteristics of pesticide container materials and with analysis of the ash remaining after incineration of these materials.

Temperatures of complete combustion have been determined by the differential thermal analysis method for the following seven pesticide container materials and caps (closures): teflon, polypropylene, milk carton paper, lithate 2, 4-D paper, amber polyethylene, clear polyethylene, and polyvinylchloride. These temperatures are presented in table 4. As evidenced from the data, containers and caps, burned singly or mixed (1.1 ratio by weight), were completely combustible at temperatures between 550 and 700° C., with 800° C., being the safe upper limit. These temperatures are also within the range at which pesticidal chemicals (table 5) were found to be completely incinerated[9]. Based on these results, one is led to believe that, under practical conditions of burning in an incinerator, containers and chemicals could be incinerated together. Table 5 also compares the combustion temperatures of mixtures of the seven containers and 20 selected pesticide formulations. The formulations used were: 2, 4-D, picloram, atrazine, diuron, trifluralin, bromacil, DSMA, DNBP, dicamba, dalapon, paraquat, vernolate, 2,4,5-T, carbaryl, DDT, dieldrin, malathion, PMA, zineb, and DBCP. It is shown by the data that the combustion temperature of the mixture of containers (650° C.) is the same as that of the mixture of the containers plus the 20 formulations. Each of the temperatures of combustion presented in the table is well below the temperature of 900° C., which is the presently considered safe incineration temperature.

Table 4. Combustion, temperatures of containers and container caps[1]

Material	Combustion temperature, ° C. Container	Cap
Teflon	700	650
Polypropylene	550	550
Paper carton (milk carton)	550	–
Paper carton (lithate 2, 4-D) . . .	600	–
Amber polyethylene . .	600	600
Clear polyethylene . . .	650	650
Polyvinylchloride . . .	700	700
Mixed containers	650	–

[1] Determined by differential thermal analysis method.

Table 5. Combustion temperatures of formulation and container mixtures

Mixtures	Degrees centigrade
Wettable powders (8)	750
Liquids (12)	600
Wettable powders + liquids (20) . . .	700
Combustible containers (7)	650
Wettable powders + liquids + containers (27)	650
Mean of singly-combusted formulations	665(508-850)
Mean of singly-combusted containers	622(550-700)

The rate of burning of combustible containers is dependent, among other factors, upon the rate at which air is being supplied to the furnace. This factor was tested in the laboratory by burning the seven container materials described earlier in a dry combustion furnace in the presence of oxygen (using platinized asbestos as a catalyst) and in the presence of air freed from carbon dioxide. The source of oxygen was bottled gas, and that of air, the natural air. Incineration in air was conducted with a single furnace and with two furnaces hooked up in series, respectively. When oxygen was used, it was passed through the combustion tube at a low rate of 60 ml./min., while when air was used, it was passed at 60 ml./min. with the single furnace and at 120 ml./min. with two furnaces. Carbon dioxide which was evolved during the burning was collected, measured, and used to estimate the completeness of combustion of the respective materials. Table 6 presents the total carbon contents obtained from combustion of the seven containers. It is quite obvious that at comparable rates of gas flow and burning arrangements, oxygen supports by far more

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[9] Kennedy, M. V., Stojanovic, B. J., and Shuman, F. L., Jr., Chemical and thermal methods for disposal of pesticides. Residue Reviews 29: 89-104. 1969.

Table 6. Percent carbon in pesticide container materials incinerated at 900° C.[1]

Container material	Percent carbon		
	Oxygen (60 ml./min.)[2]	Air (60 ml./min.)[2]	Air (120 ml./min.)[3]
Clear polyethylene	75	37	73
Amber polyethylene	81	34	71
Polypropylene	80	38	64
Polyvinylchloride	40	31	41
Teflon	29	23	23
Paper (lithate 2, 4-D)	47	32	44
Paper (milk carton)	44	36	44
Mixture of above materials	—	40	52

[1] Dry combustion methods.
[2] One furnace used.
[3] Two furnaces in succession used.

complete combustion than does air. The somewhat poor recovery of carbon in air is attributed chiefly to the lean supply of oxygen to the furnace affecting the "starvation" of the combustion process for oxygen. As is evident from the data, the burning in air is improved significantly by doubling the flow rate and employing two furnaces in series, i.e., having a "burning after burning" effect. Teflon, however, appears to be insignificantly affected by the flow rate and type of gas during incineration.

Along with these tests, others were conducted to obtain information about the quantity of ash that would remain as an inorganic residue in the furnace. Table 7 shows the percent ash left after incineration of the containers. These percentages appear to be relatively small; however, in the event of incineration of large numbers of containers, this ash could represent a substantial amount of incombustible residue which has to be disposed of by some means other than incineration.

Table 7. Ash residue obtained from incineration of container materials at 900° C.[1]

Container Material	Percent Ash
Clear polyethylene	0.12
Amber polyethylene	0.22
Polypropylene	0.21
Polyvinylchloride	0.01
Teflon	0.00
Paper carton (lithate 2, 4-D)	0.30
Paper carton (milk carton)	0.62

[1] Incinerated in a muffle furnace.

Analysis of the ash from incineration of lithate 2,4-D and milk carton by X-ray spectroscopy (table 8) revealed the presence of a wide range of elements, some of which had not been anticipated to be constituents of these two kinds of containers.

Table 8. Elemental composition of container ash[1]

Container	Principal elements	Minor elements
Paper carton (Lithate 2, 4-D)	Al, Ca, Fe, I, Ti	Pd, Si, Zn
Paper carton (milk carton)	Ca, I, S, Ta	None

[1] Incinerated in a muffle furnace at 900° C.

SUMMARY AND CONCLUSIONS

The use of pesticides to increase farm production has created problems concerning the disposal of pesticide containers without polluting our environment. Today almost one million containers must be disposed of annually in Mississippi alone. The most common disposal methods for containers are burning, dumping, burying, or a combination of these procedures. These methods are not only expensive but are objectionable from the viewpoint of air pollution or contamination of the soil at the disposal sites.

Incineration of pesticide containers in a well-designed incinerator equipped with devices to entrain the hazardous gases and particulate matter emitted during incineration appears to be the most feasible means for disposing of containers. Complete combustion temperatures of individual combustible containers and pesticides are readily attainable by conventional incineration methods. These temperatures also indicate that mixture of these substances could be incinerated together. The completeness of incineration is dependent on both the type of gas (air or oxygen) used to support combustion and the flowrate at which the gas is passed through the incinerator. In addition, the ash remaining after incineration may contain toxic elements, such as zinc, arsenic, or mercury, which were originally present in the container or pesticide materials.

It is apparent that, from the practical viewpoint, the most suitable type of incinerator for burning of combustible pesticide containers would be an incineration system containing two or more combustion chambers ("burning after burning"). Such a system would allow for most of the burning to take place in the first chamber, while the other chambers would ensure more complete combustion of particulate matter ("fly ash") which could have escaped the first chamber. This kind of system equipped with accessory devices for complete scrubbing of noxious gases from the incinerator stack appears to offer the most desirable features that are necessary for ridding the environment of haphazardly disposal of containers and for promoting a clean environment.

ENVIRONMENTAL QUALITY IN FLORIDA AND RELATED RESEARCH PROGRAMS

by
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This presentation was made from an outline based upon 5 papers presented by my colleagues and me at our FIFTH Annual DARE Conference on March 4, 1971. The five papers listed below may be obtained by sending for a copy of:

> THE DARE REPORT — 197. Agriculture and the Environment. Publication No. 10, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Fla. 32601. March 1971.

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1. Improving Man's Environment by Use of Plants Dr. James W. Strobel, Chairman Ornamental Horticulture Department	22
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SESSION III: ABATEMENT OF POLLUTION IN PROCESSING — B. H. Wojcik, Southern Marketing and Nutrition Research Division, Chairman

ABATEMENT OF POLLUTION IN PROCESSING COTTON TEXTILES

by
Ralph A. Rusca
Southern Marketing and Nutrition Research Division

INTRODUCTION

The primary objective of the Southern Marketing and Nutrition Division's (SMNRD) research is to increase the utilization of Southern-grown agricultural commodities through the development of improved processes and products. While it is only recently that the abatement of environmental pollution has been formally stressed, improved processing efficiency has always been a major part of the Division's research, and increased efficiency goes hand in hand with reduced waste. The less waste, the less air or stream pollution!

My remarks will be restricted to pollution problems associated with dry- and wet-processing of cotton into textile products and progress made in these areas.

Mechanical textile processing

Mechanical, or dry, processing refers to the technology of converting baled cotton fiber into gray goods — that is, fabrics that have not been bleached, dyed, or resin treated.

With one exception, which will be discussed later, mechanical processing contaminates the air rather than the water. Factors influencing levels of dust and fly (short fibers) liberated during textile processing can be placed in two major categories — raw cotton quality and mill processing conditions.

Cotton quality

Factors affecting cotton quality include variety (1), growing conditions, harvesting methods, and ginning practices. A number of major varieties of cotton are grown in the United States with Classer's lengths ranging from 7/8 to 1-1/2 in. Regardless of Classer's length, cotton contains fibers of many lengths. As indicated in the fiber array in figure 1, this 1-1/16 in. staple length cotton contains fibers ranging in length from 1/3 to 1-1/2 in. (9). The fibers 3/8 in. and shorter are the most apt to contribute to air pollution during processing.

Methods of harvesting have a considerable effect on the foreign matter in cotton (4). Before World War II, all of the cotton harvested in the United States was hand-picked. In 1969, over 97 percent of the cotton harvested in the United States was machine-picked. Table 1 illustrates the difference in grade and foreign matter of hand- and machine-picked cotton harvested from the same field on the same day and ginned on the same equipment. The machine-picked cotton has 2-1/2 times more foreign matter than the hand-picked cotton (11). Of course, the machine-picked cotton could have been cleaned at the gin to about the same grade as the hand-picked. In this case, the additional foreign matter would have been a pollution problem for the ginning industry instead of the textile industry.

Table 1. Grade and trash content of hand- and machine-picked cotton

Cotton	Grade	Foreign Matter
Hand-picked	M Bright . . .	1.9 percent
Machine-picked	SLM . . .	5 percent

Both short fibers and foreign matter contribute to dust and fly in textile processing.

Mill-processing conditions

There is little factual data publicly available on levels of air pollution in textile mills, and even less on the quantity and type of contaminants. A survey of the technical literature reveals incomplete and cursory studies pertinent to dust and fly levels at the various textile processes. However, several years ago a study was conducted in the SMNRD which involved an analysis of 950 bales of cotton of widely varying grades and staple lengths, machine-picked and hand-picked, for 3 crop years (8). The picker and card waste from textile processing were also obtained on these bales.

The results presented in table 2 are indicative of the foreign matter and short fiber in cotton that causes dust and lint in textile processing.

Table 2. Waste analysis of 950 cottons[1]

	Shirley Analyser waste[2]			
Bales	Total Range	Visible (trash & fiber)	Invisible (dust)	Picker and card waste
Percent	Percent	Average percent	Average percent	Percent
0.6	0.00-1.00	0.66	0.18	6.1
27.2	1.01-2.00	1.00	.68	6.8
41.8	2.01-3.00	1.48	1.00	7.5
17.9	3.01-4.00	2.28	1.17	8.5
5.0	4.01-5.00	3.11	1.35	9.4
3.0	5.01-6.00	3.88	1.58	10.6
1.8	6.01-7.00	4.79	1.68	11.5
1.3	7.01-8.00	5.71	1.74	12.4
1.4	8.01-up	8.57	1.71	15.0

[1] From 1960, 1961, and 1962 crop years.
[2] Determined by Shirley Analyser Method, ASTM D1451-67.

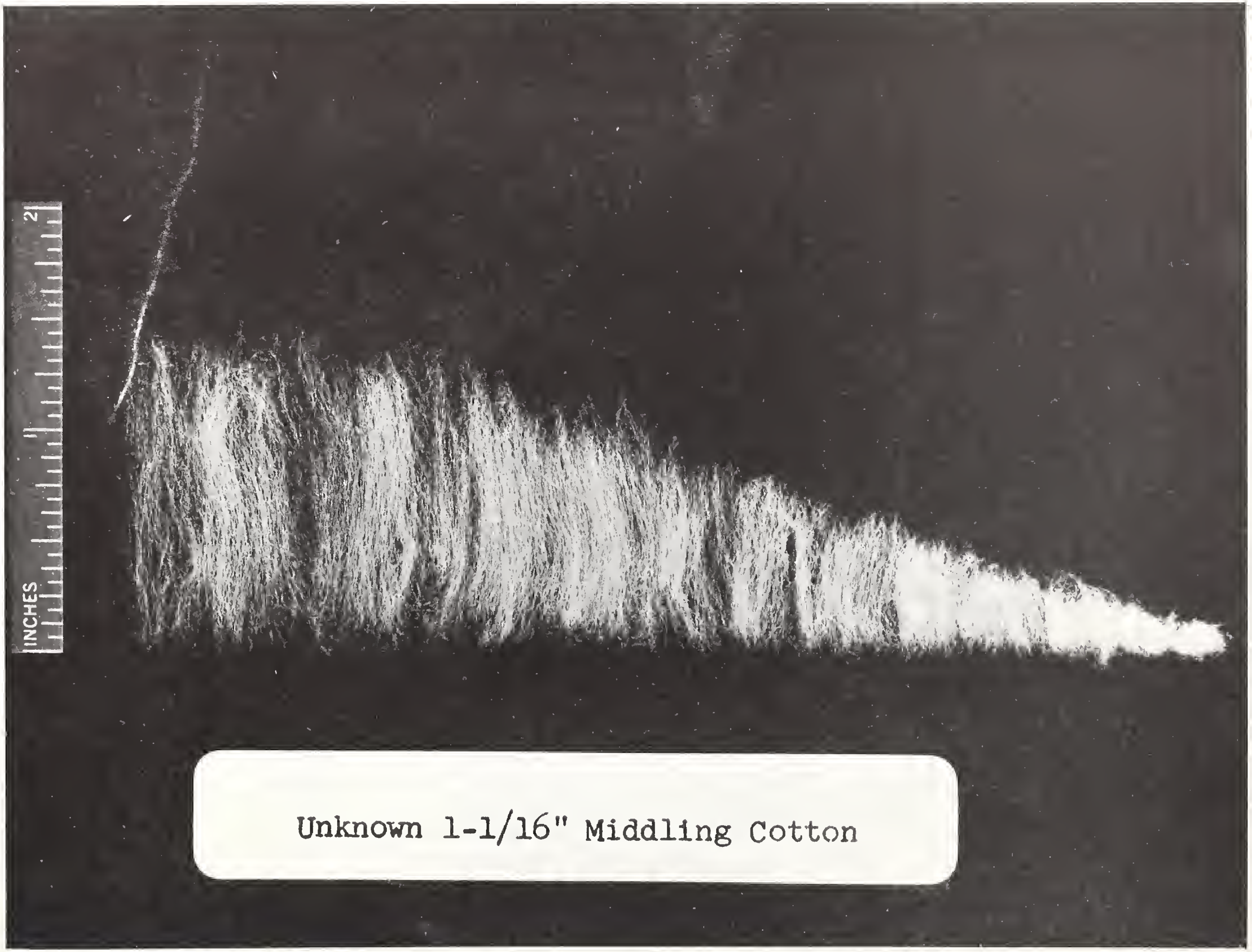

Figure 1. Fiber array of 1-1/16 inch cotton

Eighty-seven percent of the cotton bales had trash contents from 1 to 4 percent and averaged 1.6 percent. In testing these bales with the Shirley Analyzer, an invisible waste loss of 0.95 percent was experienced. This loss is composed of fine dust and fiber particles that escape the collection and air-filtration systems.

Assuming that all of this invisible waste becomes airborne during textile processing, which is probably not true, a typical 41,500 spindle mill converting 150,000 pounds of cotton per week into printcloth would have discharged 1,425 pounds of dust into its atmosphere in a 144-hour interval. This would amount to scattering about 10 lb. of dust and fly per hour throughout the approximately 1.4 million cubic foot volume of the mill.

Air pollution within a mill depends to a large extent upon the end product the mill is producing. For example, osnaburg and tobacco cloth are made from short-staple, low grade cottons that liberate much dust and fly. Drills, twills, and sateens are made from medium staple, medium grade cottons that have less dust and fly. Broadcloths, ginghams, and Bedford cords are made from longer staple, good quality cottons.

Table 3 shows two mill mixes of different grades of cotton having the same staple length. Mix A is strict good ordinary grade, 1-3/32 in. staple. Mix B is strict middling grade, 1-3/32 in. staple. The cottons were processed identically. The difference in grade resulted in 2-1/2 times more waste is being removed from Mix A than from Mix B. The mill processing Mix B would have very little dust and fly in the air, as compared to the other mill.

Table 3. Effect of cotton grade on textile processing waste

Process	Mix A	Mix B
	Percent	Percent
Breaker and finisher picker .	3.69	0.72
Card flat strips	5.90	3.35
Card cylinder and doffer strips	4.05	1.99
Motes and fly	5.80	1.67
Sweepings	0.44	0.21
Total waste	19.88	7.94

It is generally agreed that dust and fly are most prevalent in the textile processes of opening, cleaning, and carding. The Southern Division's machinery-development research has been active in these areas, with considerable success in minimizing air pollution. Several of these developments will be discussed briefly.

Developed in 1958 and now manufactured worldwide, the SRRL Opener-Cleaner is a high production, highly efficient textile machine for opening cotton to the state it was in at the gin before baling, and for cleaning the cotton (9). The machine has twice the production rate and about three times the ability to remove foreign matter from cotton compared with conventional textile cleaners. Specifically, at up to four bales per hour production, it takes out 30 to 40 percent of the trash and dirt. The Opener-Cleaner is completely sealed except for a narrow opening for feeding, and even this can be closed on most installations. A commercial model Opener-Cleaner is shown in figure 2. The amount of dust and fly from this machine is negligible.

After partial cleaning of the cotton, the next textile process is carding (figure 3). The card separates the masses of cotton into individual fibers, completes the cleaning, and forms the fibers into a thin web. The nature of the process and the equipment is such that it is the worst air contaminator in the mill. The major culprit is the flats, a series of spaced flat bars covered with several hundred thousand sharp wires. The main cylinder is also wire-covered, and as it rotates the cotton is "carded" against the flat wires. Dust, trash, and short fibers escape through the flats into the atmosphere. Most modern cards have dust removal systems that alleviate air pollution, but some contamination still occurs.

The SRRL approach was to eliminate the source of the trouble by replacing the flats with a rigid airtight cover. Carding is accomplished by coating the underside of the cover with aluminum-oxide granules bonded to an adhesive-backed fabric. The sealed cover eliminates the major source of dust and fly in carding.

The SRRL Granular Card (figure 4) is the first radical change in carding since the principle of the machine was invented over 200 years ago. Labor likes the dust-free operation of the Granular Card and the machine is becoming increasingly popular. In 1970, licenses of the USDA patent report 8,200 Granular Cards in use, or about 16 percent of the cards in the United States.

Our Machinery Development scientists have also developed recently a portable condenser that efficiently separates cotton fibers from highspeed conveying air. The condenser has a highly efficient dust and short fiber filtering system that enables discharging clean air directly back into the building, thus reducing pollution and decreasing the air conditioning load. The compact condenser is shown in figure 5.

New processing system

The Opener-Cleaner, Granular Card, and Portable Condenser are valuable in reducing air pollution with the existing mechanical textile

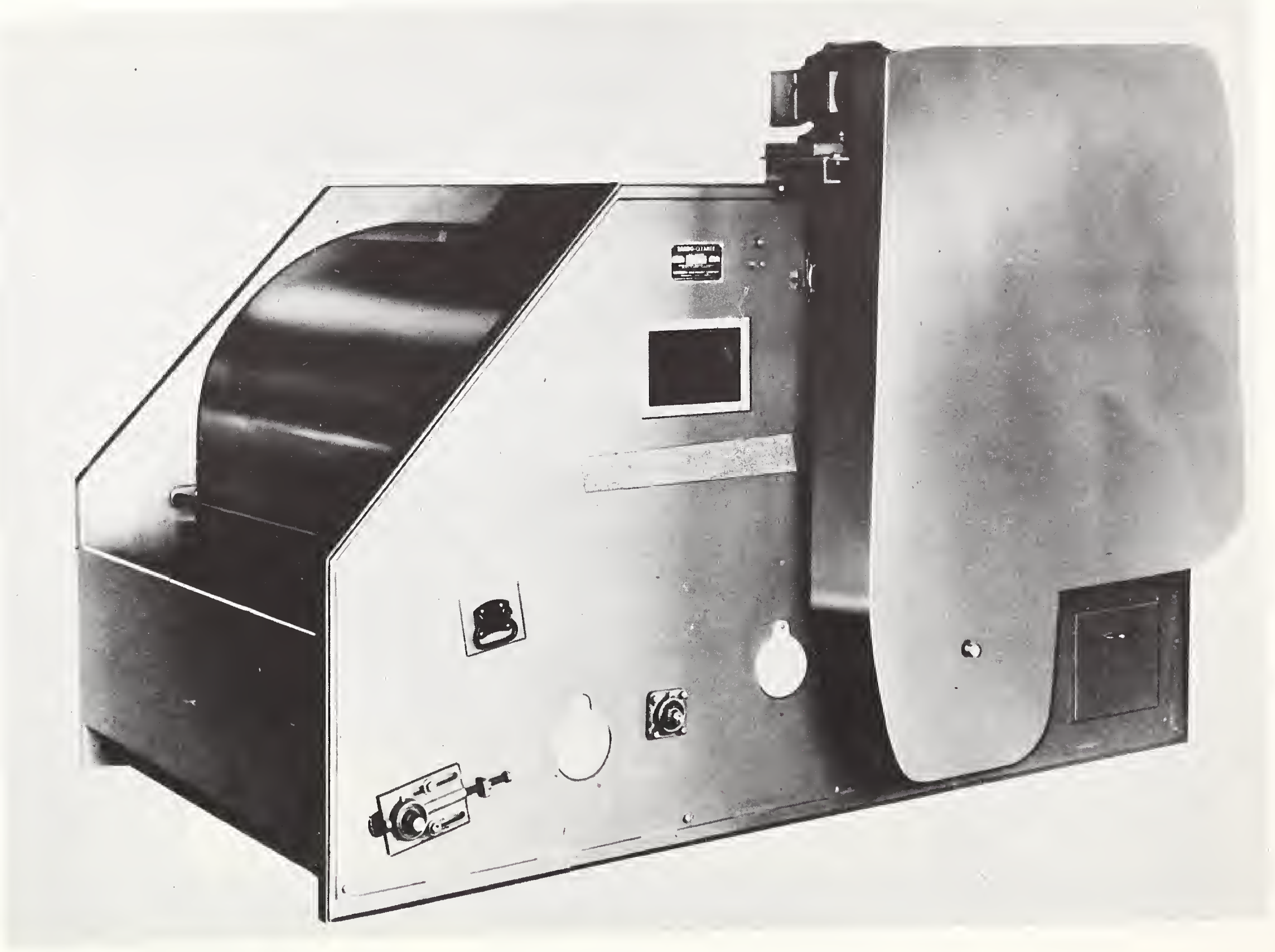

Figure 2. Photograph of commercial model of the SRRL opener.

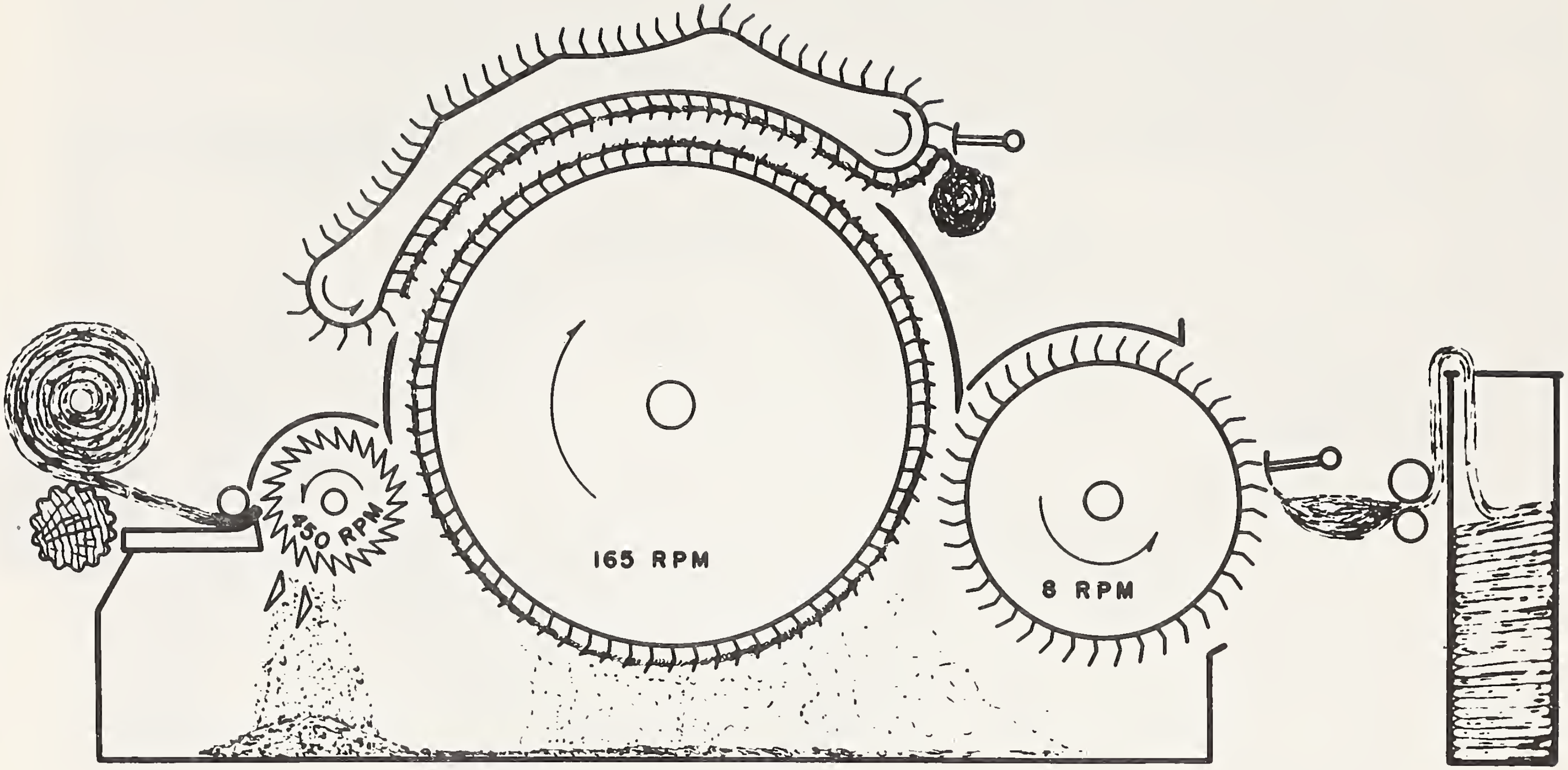

Figure 3. Schematic diagram of a conventional flat card.

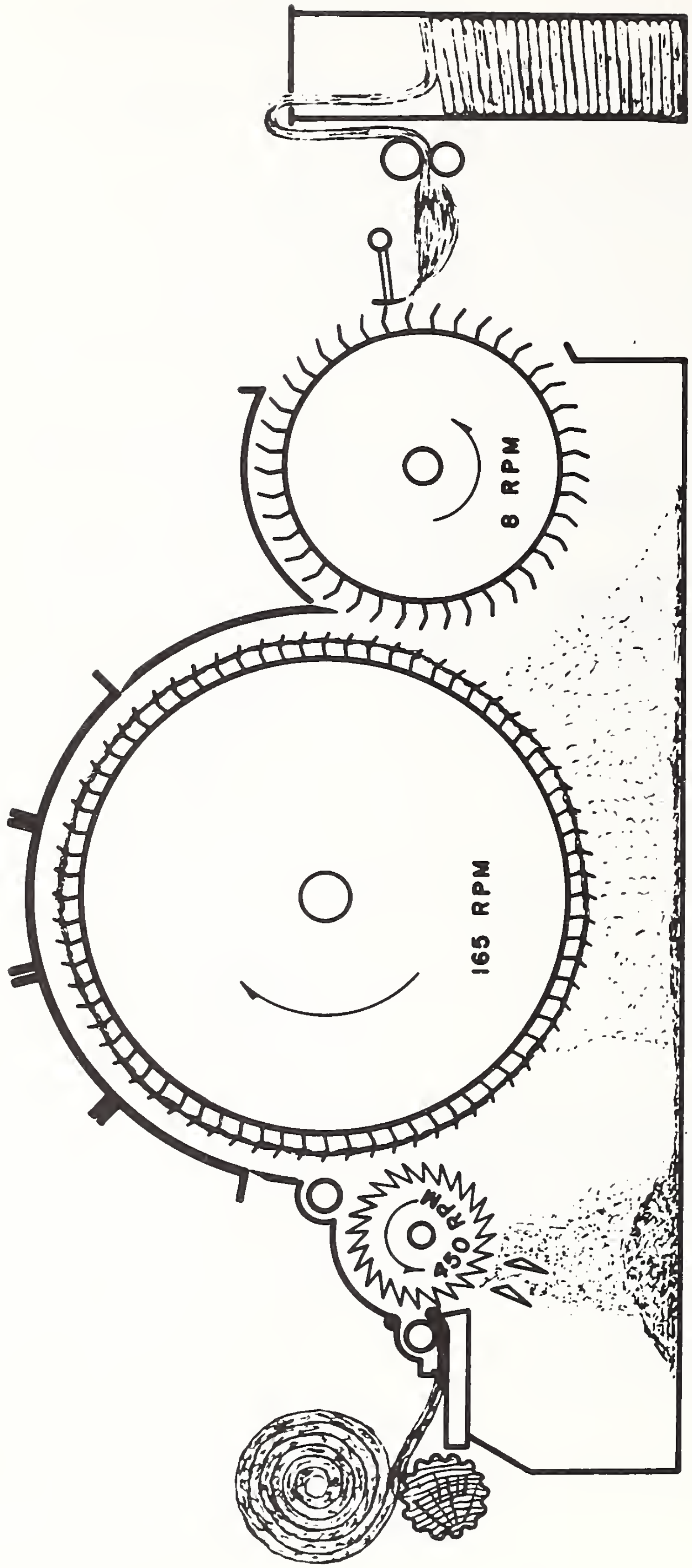

Figure 4. Schematic diagram of the SRRL granular card.

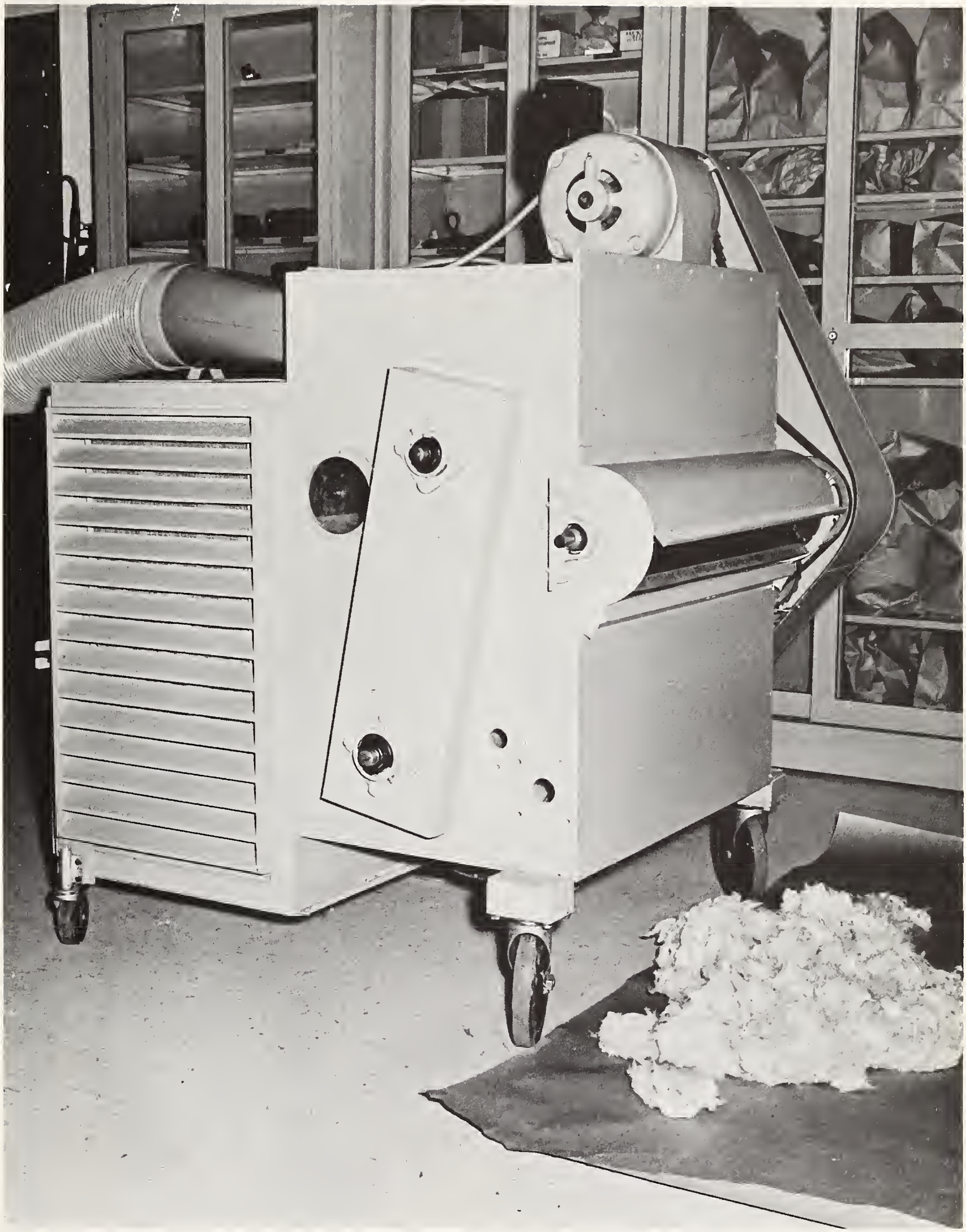

Figure 5. Photograph of the SRRL portable condenser.

processing system. However, for many years it has been our firm belief that a fundamentally new, hermetically sealed system for continuously processing fibers into yarn is the only real solution to the pollution problem (7).

Research with this objective is in progress in SMNRD (5). Basic studies are being conducted in aerodynamics, ultrasonics, electrostatics, and other modern techniques seeking to establish an approach or approaches to the new system. The results are promising; the hardware stage is being reached more rapidly than anticipated. In less than 10 years we hope to have a fully automatic, closed processing system that will produce yarn with no possibility of dirt, trash, fly, or other particles escaping into the atmosphere.

In corollary research, a multiple-section card is under development designed especially for processing low-quality, trash cotton into quality textile products. Such cottons tend to liberate much dust and short fiber into the air. An original design filter system cleans the air at strategic points and reclaims any contaminants. Although the card sections are not entirely enclosed, no dust or fly is apparent after many hours of operation. This concept of carding appears feasible in existing textile mills as well as in the proposed new processing system.

WET TEXTILE PROCESSING

Up to this point we have discussed research to diminish air pollution from dry textile processing. Now let us consider water pollution from textile finishing.

Historically, most textile mills and finishing plants have been located near rivers or streams, where large quantities of water are available. This proximity means that large quantities of textile effluent are discharged into streams as an economical means of disposal. Purification of textile wastes is much more complex than most other industrial pollution problems because of the wide variation in the types of wastes. The wastes from desizing, scouring, and mercerizing constitute about 70 percent of this objectionable effluent. Several recent developments at the Southern Division should help alleviate pollution from these stages of textile finishing.

It was mentioned earlier that one process in manufacturing fabric is a source of stream pollution. This is the "slashing" or "sizing" process, wherein yarns are impregnated with a solution of starch and other materials to impart sufficient strength and abrasion resistance for the yarns to withstand being woven into fabric. After weaving, these sizing materials are removed by wet treatment and the effluent goes into the mill's waste disposal system. A recent development of the Division is permanent sizing, which eliminates the usual desizing process that causes so much stream pollution (3). The new permanent sizing consists of polymers such as polyurethanes or polyacrylates applied to yarn before it is woven. In addition to its usefulness in reducing pollution, permanent sizing confers another advantage: A lower concentration of crosslinking agents can be used to produce durable-press fabrics with improved strength and abrasion resistance. A commercial slasher (figure 6) is used without modification to apply the permanent sizing. The process is being evaluated by several textile mills.

In a second development, an improved liquid ammonia mercerization process has been devised to replace conventional mercerization using sodium hydroxide (2). The ammonia can be reclaimed, and the organic material removed from the fabric can also be collected and utilized. There are other advantages: Not only is ammonia mercerization faster than conventional mercerization, but its use leads to considerable improvement in the properties of durable-press fabrics. Through the use of an eleven-roll chainless mercerizer (figure 7) developed at the Southern Division, it is now practicable to mercerize fabrics under tension of a continuous basis.

Processes for ammonia mercerization have also been announced abroad (10). Liquid ammonia is being used commercially to mercerize cotton sewing thread in the United Kingdom, and a process aimed at mercerizing fabrics is expected to be commercialized soon in Norway.

Eliminating or reducing effluent from individual steps in the finishing of cotton, as just described, is one approach. Another approach is the use of nonaqueous agents throughout the total system of cotton finishing. Processes for the preparatory steps are already available either commercially or on a laboratory scale. New methods are being studied at the Southern Divsion for applying durable-press finishes to cotton fabric from organic solvents (6). The pilot-plant equipment is shown in figure 8. The durable-press finishing process now used commercially is a pad-dry-cure process and therefore does not itself involve the discharge of effluent. However, development of a nonaqueous system for durable-press finishing could provide the last link needed to permit industrial use of a completely nonaqueous finishing system.

Other proposed lines of research should have benficial effects on curbing pollution, including:

(1) Antisoiling investigations will benefit the environment because small quantities of detergents, phosphates, etc., will be fed into the waterways.

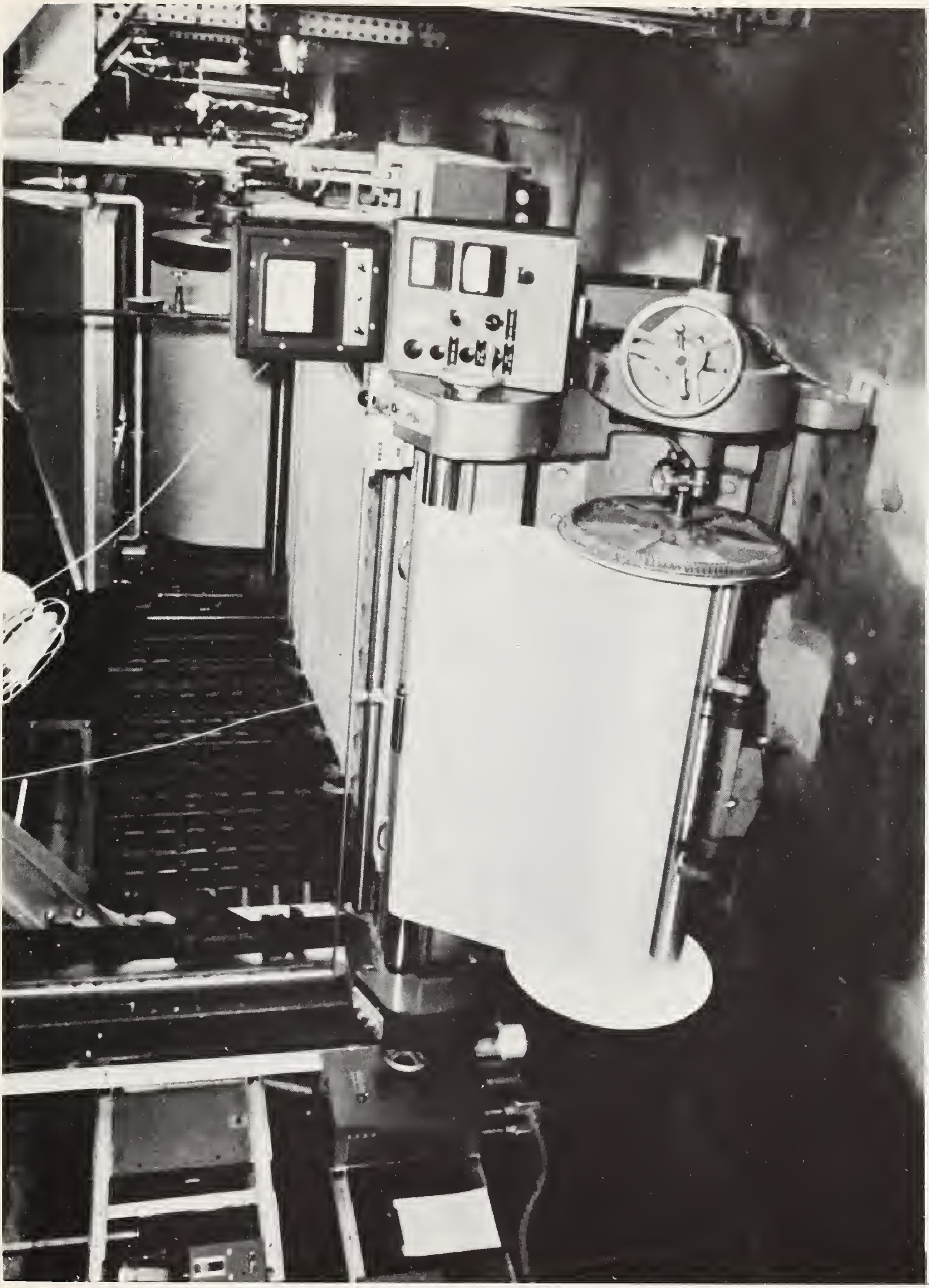

Figure 6. Photograph of textile slasher.

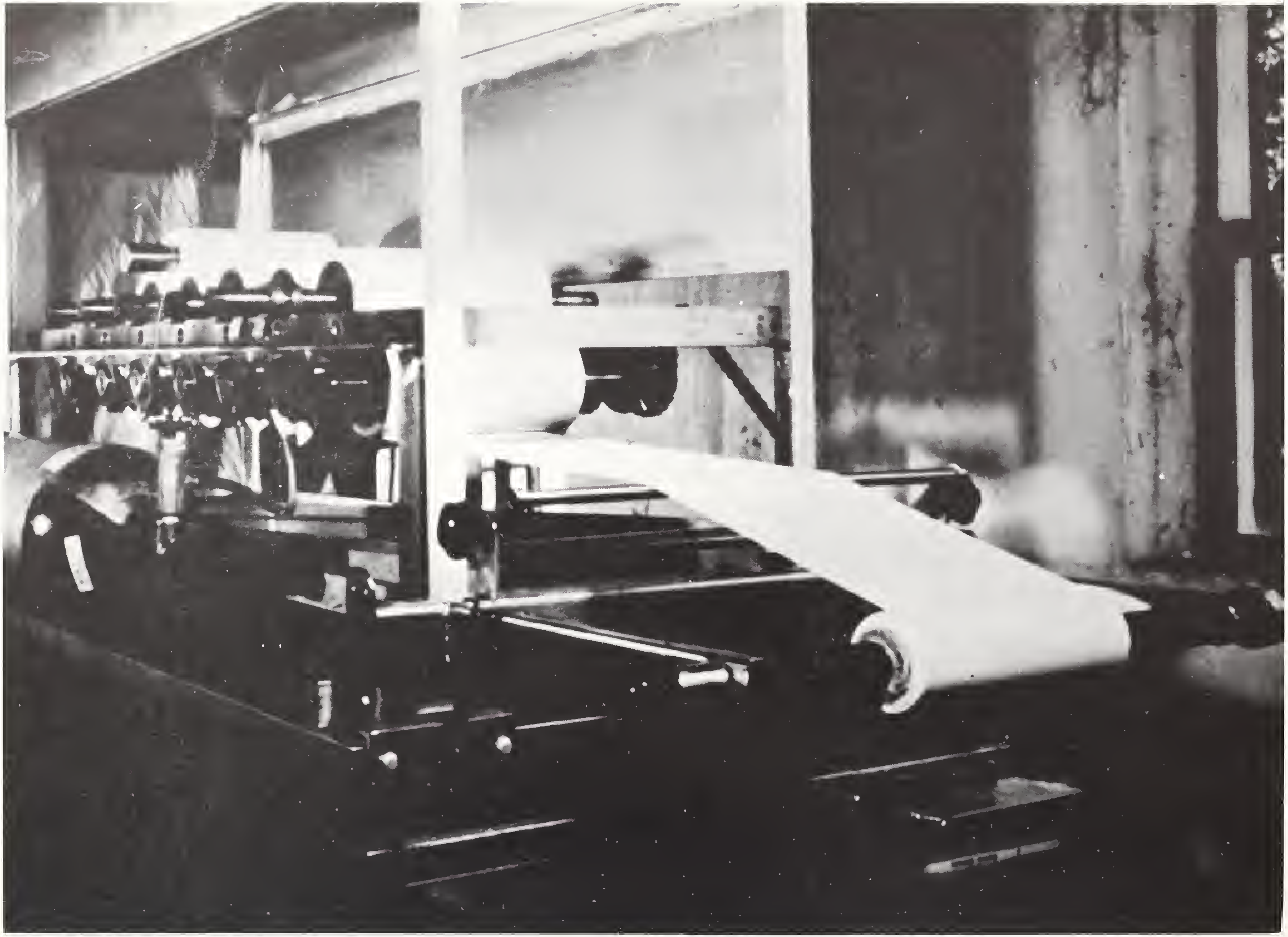

Figure 7. Photograph of SRRL chainless mercerizer.

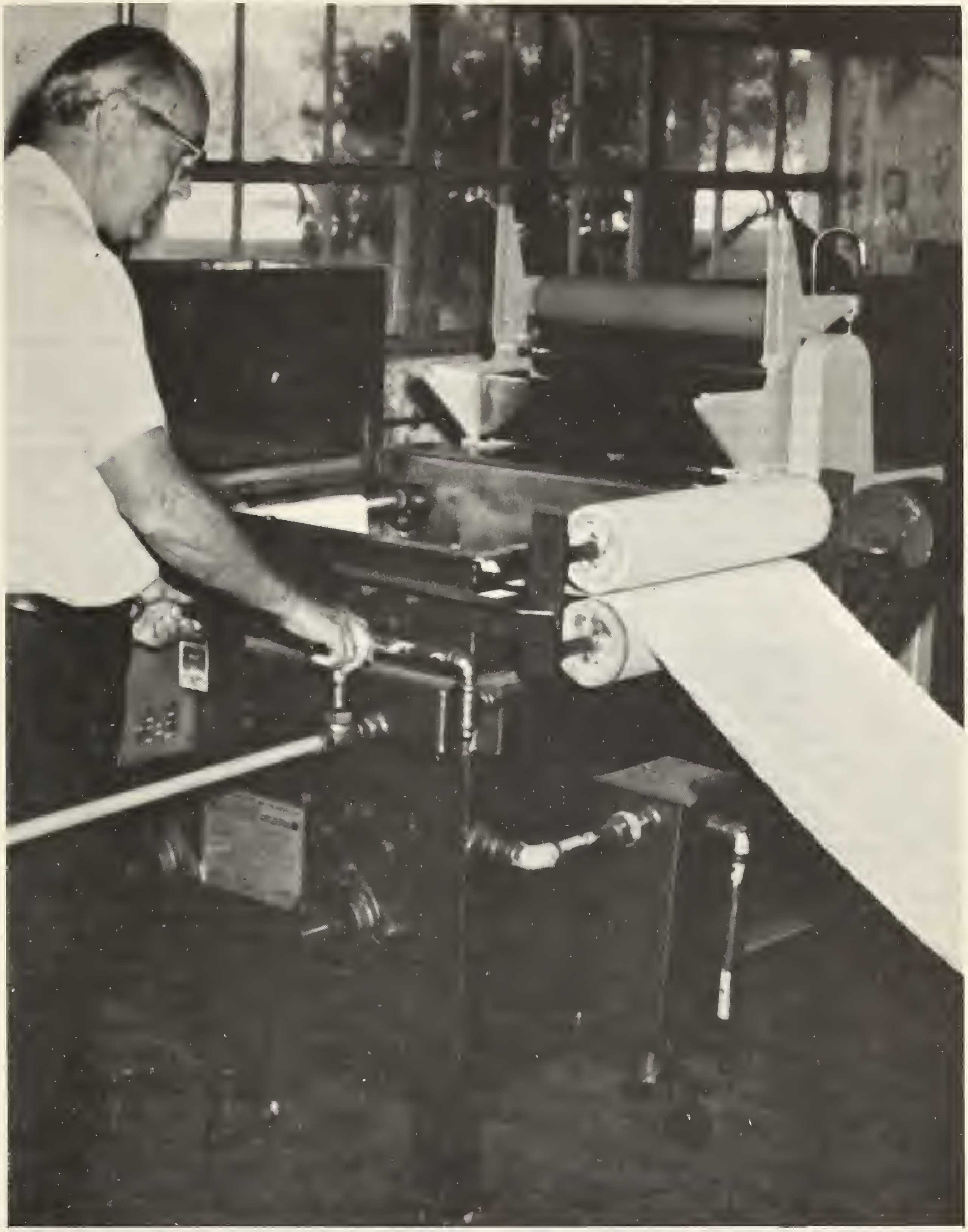

Figure 8. Photograph of organic solvent pilot plant.

(2) Bleaching with hydrogen peroxide and with other bleaches that do not produce undesirable byproducts that pollute the waterways.

(3) Recovery of waxes and fats from cotton (perhaps by solvent extraction) to avoid adding wastes to streams and lakes. Possibly the waxes and fats could be used in producing chemical products for some worthwhile purpose.

(4) Treatment of textile fibers with selected chemicals prior to processing. Such chemical treatments might facilitate processing, diminish dust in the processing areas, and generally improve the overall environment.

The Federal Government and the States are deeply concerned with air and water pollution in textile manufacturing, and their various agencies are investigating means for alleviating the problem. Textile producing States have promulgated and are enforcing stringent stream pollution regulations. The textile industry itself is installing new processing equipment and waste disposal systems to decrease pollution. Machinery manufacturers are redesigning equipment and processes for the same purpose.

And, as you are fully aware, the State Agricultural Experiment Stations have active programs concerned with reducing pollution from agricultural commodities.

SUMMARY

We have mentioned some of the pollution problems facing the textile industry and briefly summarized several SMNRD developments that will contribute to solving these problems. No effort was made to discuss industry developments in pollution, although it is recognized that significant improvements have been made and are pending.

SMNRD will continue its research to guard the environment while improving the quality of consumer products made from agricultural commodities.

References

1. Anonymous. 1967. Six varieties have 85 percent of the total U.S. output. Textile World 119(11): 67-71.
2. Calamari, T. A., Schreiber, S. P., Cooper, A. S., Jr., and Reeves, W. A. 1971. Liquid ammonia modification of cellulose in cotton and polyester/cotton textiles. Textile Chem. Color. 3: 61-65.
3. Lofton, J. T. Harper, R. J., Little, H. W., and Blanchard, E. J. 1970. Polymer sizing and cotton DP. Textile Indus. 134(1): 56, 57, 60-64, 77.
4. Martin, W. J. 1965. Harvesting and ginning. Amer. Cotton Handbook, 3rd Ed., Vol. 1: 82-109. Interscience Publishers. New York.
5. Mayer, M., Jr., and Rusca, R. A. 1969. Progress being made toward new cotton spinning system. Amer. Textile Reptr. 83(5): 16, 17, 29.
6. Reid, J. D., and Frick, J. G., Jr. 1970. Chemical modification of cotton with applications from organic solvent. Textile Chem. Color. 2(24): 409-413.
7. Rusca, R. A. 1960. Coming: The push-button mill? Textile World 110(5): 46-47.
8. Rusca, R. A., Little, H. W., and Gray, W. H. 1964. An evaluation of the SRRL non-lint tester for determining the trash content of lint cotton. Textile Res. Jour. 34: 61-68.
9. Rusca, R. A., and Wallace, E. F. 1958. Machine removes one-third of the trash. Textile Indus. 124(4): 145-146.
10. Sucheki, S. M. 1971. The case for liquid ammonia. Textile Indus. 135(1): 112, 114-117.
11. Williamson, E. B., Shaw, C.S., Looney, Z. M., and Shanklin, E. H. 1966. Comparative effects of mechanical picking, spindles and handpicking on cotton quality and spinning performance in Mississippi, 1960-63. Market. Res. Rept. 730, U.S. Dept. Agr.

INCREASING THE AVAILABILITY OF NUTRIENTS FROM AGRICULTURAL WASTE PRODUCTS

by
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(Presented by James J. Spadaro)

Disposal of unused plant material remaining after harvest is a major problem facing many of today's farmers. The residual dry leaves, stems, chaff, cobs, and hulls are principally carbohydrate, but also contain appreciable quantities of lignin and ash. The amount of residual protein is usually very low. In a few fortunate cases, enough of the carbohydrate in the residues can be utilized directly by ruminant animals to serve as an energy source in diets. In a few others, the residue can be sold for mulch or litter. Some residues may have minor industrial applications as chemicals (oat hulls and corncobs), sweeping compounds (rice hulls), or sandblasting agents (corncobs), but these minor uses fail to use up any considerable part of the waste. Ordinarily the situation is such that the farmer must dispose of most of his waste material by the cheapest means possible.

Frequently this means plowing back into the soil, but sometimes this is impractical. When incorporation into the soil is at all feasible, it is probably the most highly desirable disposal procedure. But in the Western United States there are several examples of crops where incorporation is not practical. One is grass straw in the Willamette Valley of Oregon, and another is rice straw in the Central Valley in California. Much of the grass seed in the Northwest is grown on perennial rootstalks, so that the land cannot be plowed after harvest unless reseeding is called for. Decomposition of rice straw is very slow in the heavy, damp soils on which California rice is grown, and incorporation costs are extremely high. In many cases additional nitrogen must be added at extra expense to compensate for that used up by the soil microorganisms while decomposing the straw. Some California farmers contend that the extra expenses involved in incorporation of rice straw cut so deeply into their financial return on the crop that it is no longer profitable to grow it.

In the West the principal alternative disposal procedure to incorporation is field burning. This is a cheap, easy, and effective operation for the farmer, but it creates problems for the rest of society. The housewife gets soot and ashes in her home and on her laundry, smoke obscures highways and causes considerable inconvenience and accidents, and at times, even closes down airports. As a result, the Air Pollution Abatement authorities are forcing the Western farmer to find other means of waste disposal. In California alone, with over 350,000 acres of rice land producing about 4 tons of rice straw each, the problem of getting rid of 1.5 million tons of material is enormous.

A variety of waste including straws, sugarcane bagasse, peanut hulls, etc., contain enough cellulose to make them, in theory at least, excellent sources of energy for ruminants (sheep and cattle). Ruminants are uniquely adapted by nature to thrive on cellulose containing materials that monogastric animals cannot digest at all. Consequently, fibrous wastes represent a resource for production of red meat and dairy products that should be utilized more fully. The difficulty is that, for largely unknown reasons, the energy in these wastes is only partly available to ruminants. Some of the cellulose and hemicellulose may be tied up by lignin or silica. For example, the digestibility of rice straw is only about 30 percent, while the digestibility of good dehydrated alfalfa is over 50 percent.

At the Western Marketing and Nutrition Research Division, we have been interested in increasing the digestibility of cellulosic wastes to make them better ruminant feeds. Feed use offers the potential to open up huge new outlets for agricultural wastes and, at the same time, helps to solve a troublesome disposal problem. The farmer may even profit from a resource that up until now has been largely neglected. It should be pointed out that improved products from cellulosic wastes will only contribute energy to ruminant diets, and protein needs must be met by supplementation from other sources.

Until recently, workers doing digestibility studies with ruminants had only two alternatives: either run an in vivo trial involving feeding many pounds of a feedstuff to a number of animals for at least three weeks and carefully measuring input and output; or run in vitro artificial rumen digestions with strained, buffered rumen fluid in the laboratory. The in vitro procedure can be used to test many small samples in a relatively short time, however, it still has at least one major disadvantage — it requires the presence of a fistulated ruminant animal close at hand to supply fresh rumen fluid when needed. This requirement has deterred many otherwise well-equipped laboratories from research in this field.

Since our laboratory has no large animals, we were interested in developing some test or analysis that could be used to evaluate the effects of processing on the digestibility of cellulose. Table 1 shows the problem encountered in trying to use standard analyses to differentiate between treated and untreated materials. Samples of rye-grass straw with 50 percent added water (by weight) were processed with different amounts of alkali for 40 seconds at 231° C. The four chemical constituent analyses — acid detergent fiber, crude fiber, pentosans and lignin — showed essentially no differences between untreated and treated materials, because any apparent variability was probably within the limits of experimental error. However, the last two tests, DMD (artificial) and DMD (enzyme), do differentiate between the products. Both tests depend on biological differentiation of fiber quality and are considerably more sensitive than chemical tests. The DMD (artificial) is the previously mentioned artificial rumen type test using live ruminal microorganisms. The DMD (enzyme) is an assay we developed using commercially available cellulases and proteinases. Concurrently, a group of French workers developed a similar procedure to measure digestibility of forage by ruminants and showed a very close correlation with results of actual animal digestion studies. Our results also show excellent correlation between enzymatic and animal digestibilities for a variety of agricultural wastes.

Table 1. Treated ryegrass straw

Analysis[1]	Untreated control	40 seconds, 50 percent H_2O		
		None	1 percent NaOH	4 percent NaOH
ADF	50.6	48.8	49.4	49.8
Fiber	41.2	38.7	41.3	40.4
Pentosan	22.0	19.4	20.6	21.5
Lignin (crude)	16.5	15.2	14.9	13.7
DMD (artificial)	39.7	62.2	67.0	69.5
DMD (enzyme)	39.6	67.8	69.8	82.3

[1] Figures are percents (MFB).

Table 2. **Comparison of TSAE with TDN**

Sample	TDN (literature values)	TSAE
Milo	85.7	86.7
Wheat shorts	82.8	69.2
Sugar beet pulp	74.3	41.7
Safflower kernel (oil-free)	73.3	64.4
Wheat bran	69.9	60.5
Whole alfalfa, 20 percent protein	62.0	54.3
Alfalfa leaf meal	61.7	61.8
Whole alfalfa, 17 percent protein	58.0	52.3
Whole alfalfa, 15 percent protein	57.5	50.4
Bean straw	50.7	52.1
Oat straw	49.9	32.6
Safflower meal (oil-free)	48.8	36.9
Barley straw	46.9	37.3
Alfalfa stem	46.2	53.4
Rice straw	44.9	32.5
Wheat straw	43.8	37.2
Cottonseed hulls	43.1	30.9
Safflower hulls	16.2	20.4
Rice hulls	15.3	11.7

Table 3. **Digestibility of straws**

Straws	DMD — Enzmatic (percent)		
	Control	Steam[1]	NaOH (3 percent)[1]
		231° C., 3 min.	
Rye grass	40	49	76
Barley	37	56	83
Wheat	37	47	75
Rice	34	43	61
Alfalfa	52	61	81

[1] Liquid: solids = 2:1.

In our procedure, the amount of sample solubilized after treatment with enzyme is measured and is now called "Total Solubles After Enzymes" (TSAE). This corresponds closely to apparent dry matter disappearance (DMD) reported in in vivo studies. Enzymatic digestion times have been chosen to approximate those obtained in in vivo tests. Figure 1 shows a comparison between enzymatic TSAE and lamb DMD for samples of straw, corncobs, alfalfa, alfalfa stem, reed canarygrass, smooth bromegrass, tall fescue, and all-concentrate. Several of the wheat straw and one of the corncob samples had also been treated with sodium hydroxide. The correlation of 0.900 for all samples indicates that the method is useful for a wide variety of materials, including those treated with alkali. Note that the experimental data cover a fairly wide range of digestibilities. Figure 2 shows that when digestibilities of samples of the same kinds of plant material are compared, the correlations are usually much higher.

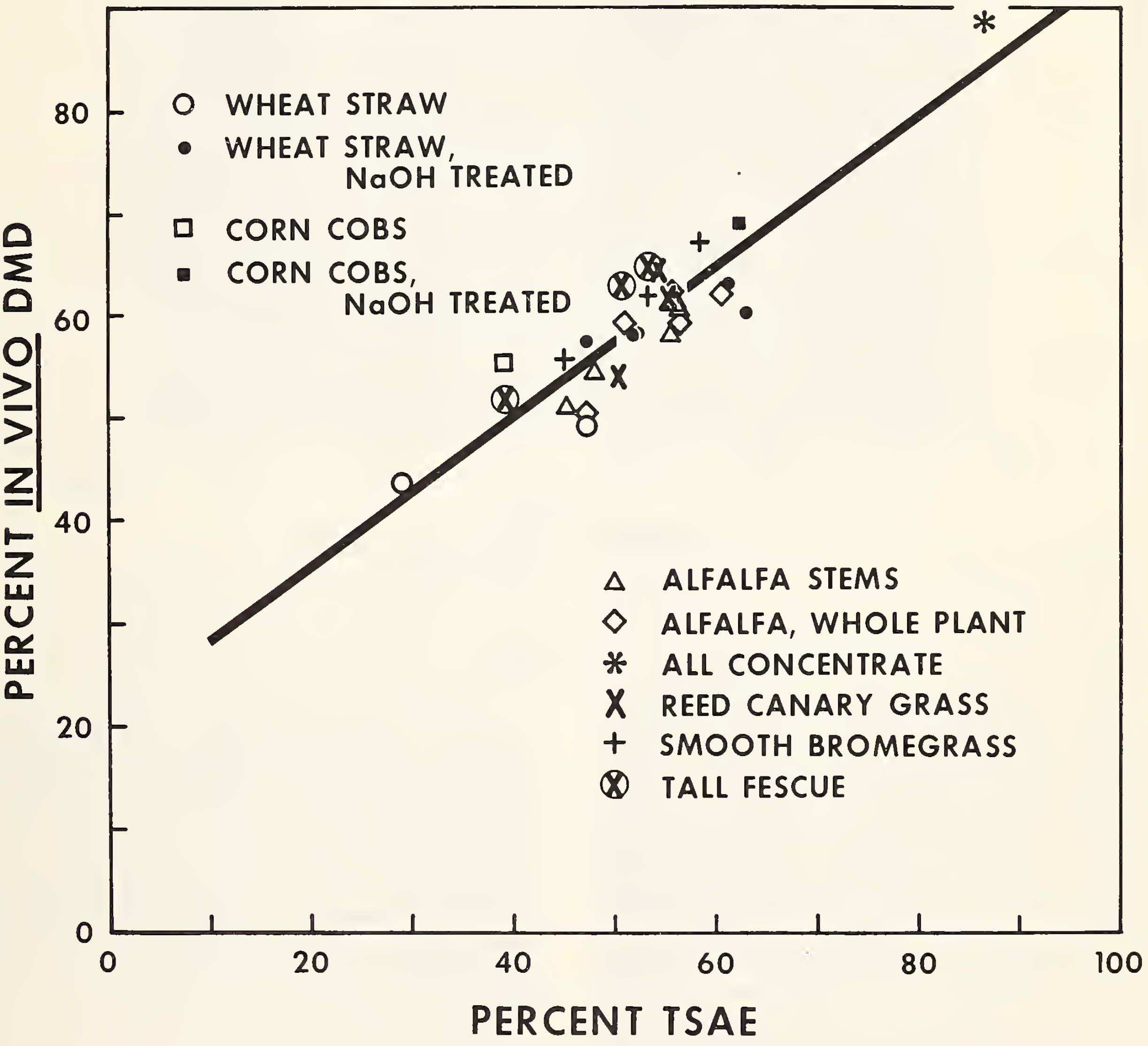

Figure 1

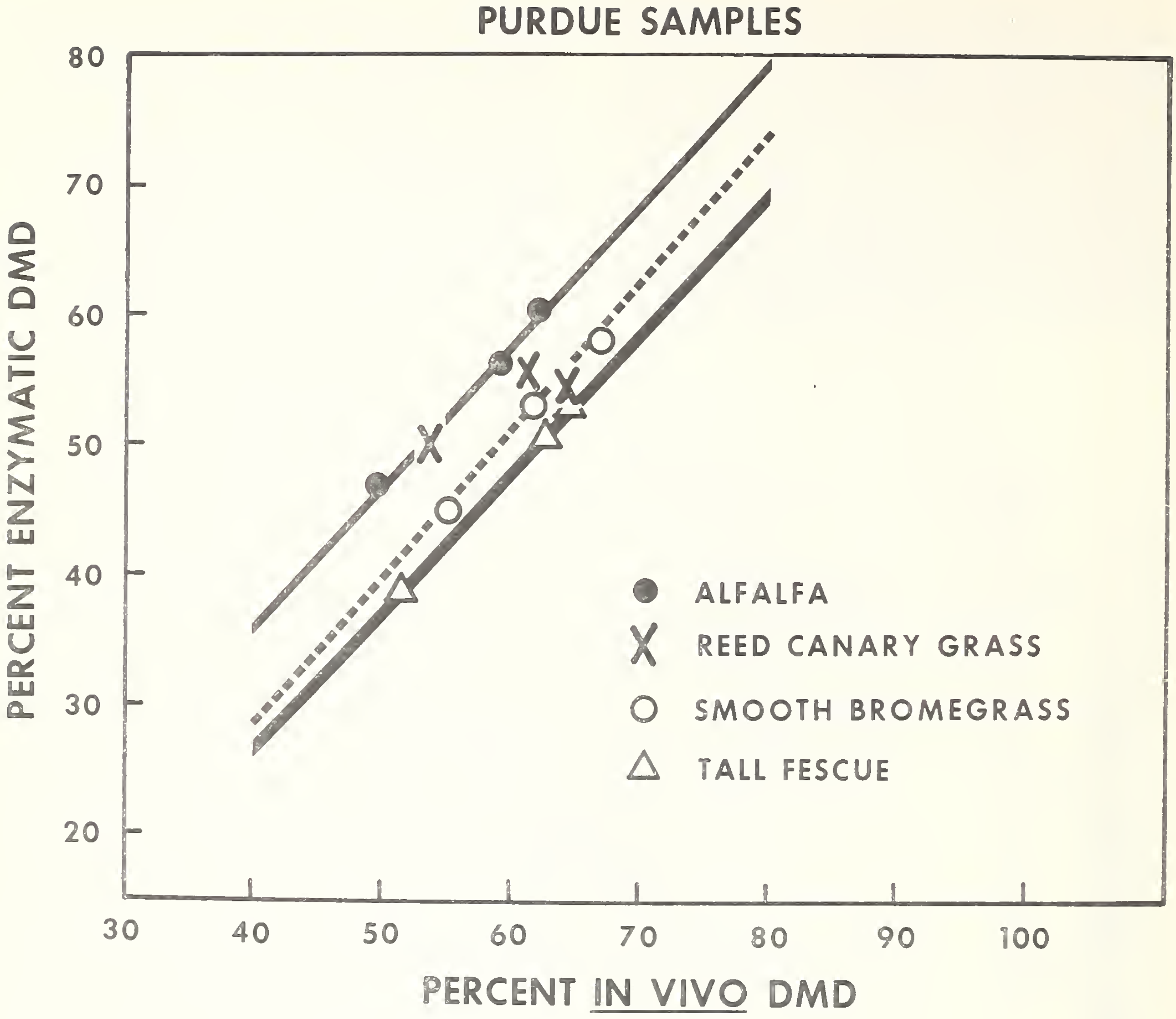

Figure 2

The enzymatic digestion results also correlate well with Total Digestible Nutrient (TDN) values in the literature. TDN values are used by nutritionists to formulate complete, balanced rations. Table 2 compares enzymatically determined TSAE's for a variety of plant materials with published TDN values for these same feedstuffs. Sugar beet pulp is the only material that does not fit the same pattern as the other plant materials, possibly because its principal carbohydrate is an arabogalactan polymer, rather than cellulose and xylan as are the others. The overall correlation between all these data is r = 0.902. If sugar beet pulp is omitted from the calculation, then the correlation is improved, as r increases to 0.941.

As indicated previously, some treatment of cellulosic residues is necessary to increase their digestibility. On the basis of literature evidence and experience, an alkali treatment seemed to us to offer the most promise. The influence of temperature, amount of water, time, type, and concentration of reagent on digestibility of a variety of cellulosic residues was investigated. Reactions at elevated temperatures and pressure up to 400 p.s.i. were carried out in small bombs made from copper or stainless tubing as shown in figure 3. Table 3 shows some typical high-temperature results obtained with various cereal straws. Alfalfa is included for comparison. It is evident that, with most of the materials tested, processing can improve TSAE values. In many cases up to 100 percent improvement was obtained. We have studied the use of potassium, sodium, calcium, and ammonium hydroxides. Potassium hydroxide appears to be equivalent to sodium hydroxide on a molecular weight basis, but because of its extra cost, it is not likely that it would be used, unless it were nutritionally desirable to change the cation balance at high levels of alkali. A larger amount of calcium hydroxide than sodium hydroxide is required to achieve the same degree of digestibility, probably because of the relative insolubility of lime. However, animals should be able to tolerate more calcium than sodium in their diet, so that the lime treatment may be preferable.

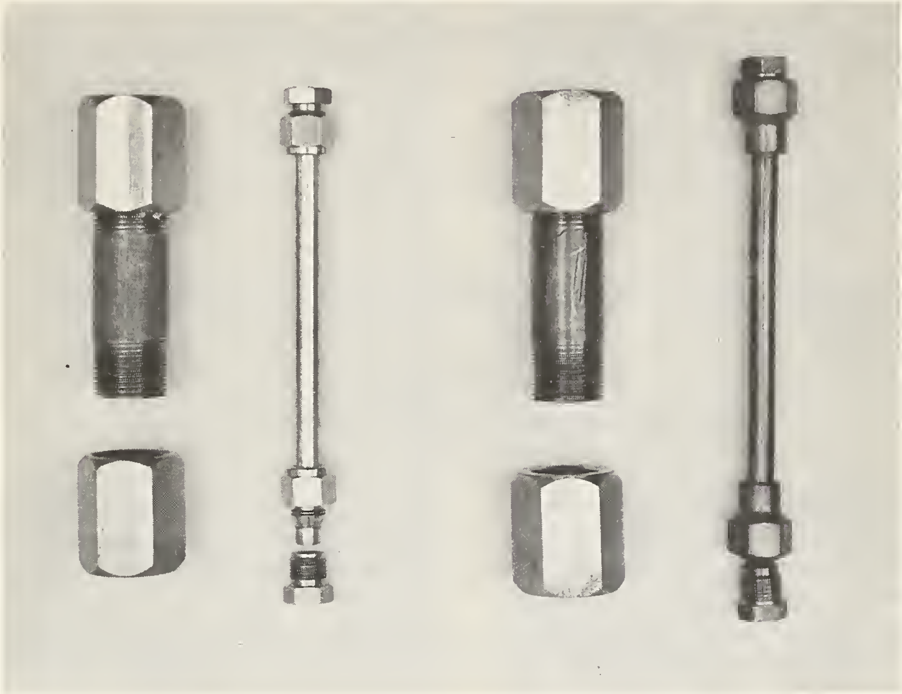

Figure 3

Perhaps of particular interest to this group are some preliminary results obtained with peanut hulls and a few other typical Southern agricultural wastes. Four peanut hull samples have been treated with steam and with 4 percent sodium hydroxide. Table 4 shows the results. The digestibility of untreated peanut hulls is very low. These samples were only 10 to 18 percent by the enzymatic method. Response to the initial treatments has been poor, the maximum TSAE values increasing only to 28 percent. Inasmuch as the sum of the ash and lignin content is only about 30 percent, the theoretical maximum digestibility of peanut hulls should be about 70 percent. Why they and similar products do not reach that potential is an interesting and potentially rewarding subject for research.

Note that of the other material, the digestibility of sugarcane bagasse can be markedly improved. We hope to study this matter further in cooperative work with Hawaiian sugarcane growers.

It is evident that we have barely started research on the feed use of agricultural wastes. We are now setting up equipment to prepare large quantities of treated materials for animal feeding tests. This is an expensive job involving a long-term research commitment, but it is the only real way to get the needed answers about effective feed use of agricultural residues.

Table 4. Digestibility of Southern crop residues. Percent TSAE

	Untreated	Steam		Steam plus NaOH		
		100° 30 min.	400 p.s.i. 3 min.	4 pct.–100° 30 min.	3 pct.–400 p.s.i. 3 min.	4 pct.–400 p.s.i. 3 min.
Peanut hulls:						
Virginia type (Florida)	18.2	17.5	19.6	27.9	24.7	28.4
Virginia type (Georgia)	13.8	13.5	16.5	22.7	19.7	---
Virginia type (Virginia)	14.9	15.2	18.9	24.5	20.8	---
Spanish type (Georgia)	9.9	9.7	17.6	17.7	16.1	20.7
Peanut skins:						
Spanish type	20.5	---	---	---	---	---
Cottonseed hull	30.9	---	46.6	---	---	---
Castor hull	48.0	---	62.3	---	73.0	---
Rice hulls	11.7	---	18.5	---	34.3	---
Sugarcane bagasse	12.6	---	45.5	---	75.6	---

[1] Total solubles after enzymes.

FERMENTATION APPROACHES TO POLLUTION PROBLEMS

by
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The Northern Marketing and Nutrition Research Division in Peoria, Ill., has become involved in several aspects of pollution research dealing with land and water. Two problems are being investigated: (1) the disposal of solid wastes from animal feedlot operations, and (2) the utilization of sludge formed during the purification of water containing grain processing wastes. Some results of these investigations will be presented here today.

Feedlot-waste disposal

The disposal of feedlot waste through utilization of its constituents requires knowledge of its composition. Accordingly, our studies have been divided into two parts: One part deals with the analysis of liquid expressed from the solid waste, and the microbial composition of the complete feedlot waste and run-off water, as well as other sites associated with the disposition of the waste. Dr. Rhodes of our Fermentation Laboratory is directing this work. The second part is concerned with the feedlot waste solids. Dr. Sloneker of the Cereal Properties Laboratory supervises this part. We shall present first Dr. Rhodes' work on the liquid portion and the microbial isolates.

Samples for Dr. Rhodes' work are obtained from Morris Farms feedlot about 40 miles southwest of Peoria.

Liquid has been obtained from solid feedlot waste by two methods, centrifugation and filtration through celite Centrifugation at 7,500 r.p.m. gives a turbid supernatant fraction. It contains approximately 2 percent dissolved solids of which 6 percent (or 1.2 mg./ml.) is nitorgen. It also has 3 mg. carbohydrate (0.3 percent and a chemical oxygen demand (COD) of 21,000 mg. O_2/liter of sample. Filtration through celite gives a clear filtrate containing only 40 percent as much nitrogen as centrifuged supernatant.

These liquors could be used as a growth medium for production of single-cell protein. Development of a successful process would achieve two of our goals, viz., (1) production of an animal food supplement, and (2) a concomitant reduction of the nitrogen content and COD of the feedlot waste fluids. In accord with this view, fermentation of recovered waste liquid is being studied. Micro-organisms isolated from whole feedlot waste and runoff water were grown successfully in pure culture in a feedlot waste liquid medium. Although nitrogen and COD levels were lowered in all cases, the best growth and the lowest nitrogen and COD values were obtained with a rhizopus sp. When feedlot liquor was supplemented with glucose, these organisms gave residual nitrogen levels 50 percent lower than those samples without added sugar, and the COD was reduced by one third. These results were achieved in 3 days, although some micro-organisms required 7 days to lower the nitrogen content and reduce the COD. In either case, refractory material was present which was resistant to fermentation. Routine tests for enzymatic activity against protein, lipids, starch, urea, and cellulose have been made with approximately 1,000 organisms isolated thus far. In conjunction with this, the number and characteristics of organisms in feedlot waste and runoff water are also determined. Samples are collected bimonthly.

The feedlot waste from Norris Farms contains 32 percent solids having 2.7 percent nitrogen but no glucose. Dr. Sloneker's group is attempting to stabilize feedlot waste solids to improve their properties as a fertilizer. They are also seeking to upgrade the material for use in animal feeds. One approach is the elimination of undigestible material from edible fractions. Another method is the separation of protein from the feedlot waste by fractionation. Upgrading the waste to provide feed could also be accomplished by fermentation of the whole waste. Utilization of feedlot waste by conversion to single-cell protein requires that the microbial species be able to degrade the carbonaceous substances present in the material. Studies are under way to achieve these goals. Producing microbial single-cell protein from nondigestible matter is not a new idea, but there is much interest in the process. The right organism and conditions must be chosen that will preclude the production of toxic byproducts. Substances such as aflatoxin and the antibiotic, gliotoxin, are extremely toxic. On the other hand, valuable byproducts might also be formed in the fermentation process.

Photochemical degradation of lignins is being studied by adding photosensitizers to solid waste suspended in liquid. It may be possible to utilize sunlight to degrade and remove waste more rapidly from lagoons by such a means.

Sludge utilization

The second major problem on which we are working concerns the accumulation of sludge formed during the purification of water. In the Peoria area, a local brewery contributes grain processing wastes, which comprise about one-third of the total BOD entering the water purification plant. Therefore, we are studying the biopolymers in Peoria's municipal sewage and the micro-organisms responsible for their production. Because little is known about activated sludge, we are investigating this material (1) to gain a better understanding of its composition and properties, and (2) to exploit potential possibilities for its commercial utilization. Activated sludge is formed during intensive microbial oxidation of sewage. It is a gummy, self-flocculating mass of microbial cells which settles rapidly in water under quiescent conditions, causing entrapment of waste matter and producing clarified water with a reduced BOD. Figure 1 shows a flow diagram of the Peoria plant.

Although Crabtree implicates poly-β-hydroxybutyrate in the process, and Tezuka theorizes that metallic cations are involved, a majority of those working with activated sludge attribute its physical activity and properties to the polysaccharides formed by certain micro-organisms which are predominant in the oxidation tanks. Friedman, Dugan, and coworkers in 1968 isolated an organism from sewage oxidation tanks and called it Zoogloea ramigera. Although there has been doubt as to the true identity of this organism, it produced capsular material on its cells that was a fibrillar polymer containing only glucose linked together by β-1, 4-bonds. It was slightly soluble in water, but it showed increased solubility in alkaline solutions, typical of a polyelectrolyte.

Activated sludge from the Peoria plant contains polymeric material which is intimately associated with the bacterial cells of the sludge. A sample of sludge was stained with giemsa stain, which causes cells to show as blackish-red to red colored masses, while noncellular material shows as a blue-green color.

In our work, some aerated sewage samples were collected in sterile jugs for purposes of obtaining bacterial isolates. Other samples were allowed to settle, and the upper water layer was discarded. After removal of more water by centrifugation, the activated sludge was extracted with boiling water. Addition of 3 vols. of ethanol to the aqueous extract gave a crude gray gelatinous product. Samples from different locations in the Peoria plant were treated in a similar manner.

When crude material was reprecipitated from 1 N NaOH solution with ethanol, a light-tan product was obtained in 2.5 percent yield on a dry weight basis. Hydrolysis in dilute HC1 and subsequent analyses by gas and paper chromatography showed that mannose and rhamnose were present, in addition to lesser amounts of galactose and other unidentified sugars. Another sample contained glucose in addition to the sugars mentioned. Treatment of polysaccharide with cellulase (from A. niger) gave free glucose, indicating the presence of β-1, 4-glucosyl bonds.

Scanning electron micrographs were prepared from an activated sludge sample before and after its extraction with boiling water. The product obtained by 2 ethanol precipitations from an aqueous extract was also photographed.

Another interesting material extracted from activated sludge is a polyester. Although poly-β-hydroxybutyrate is produced intracellularly by many bacteria as a reserve food material, our

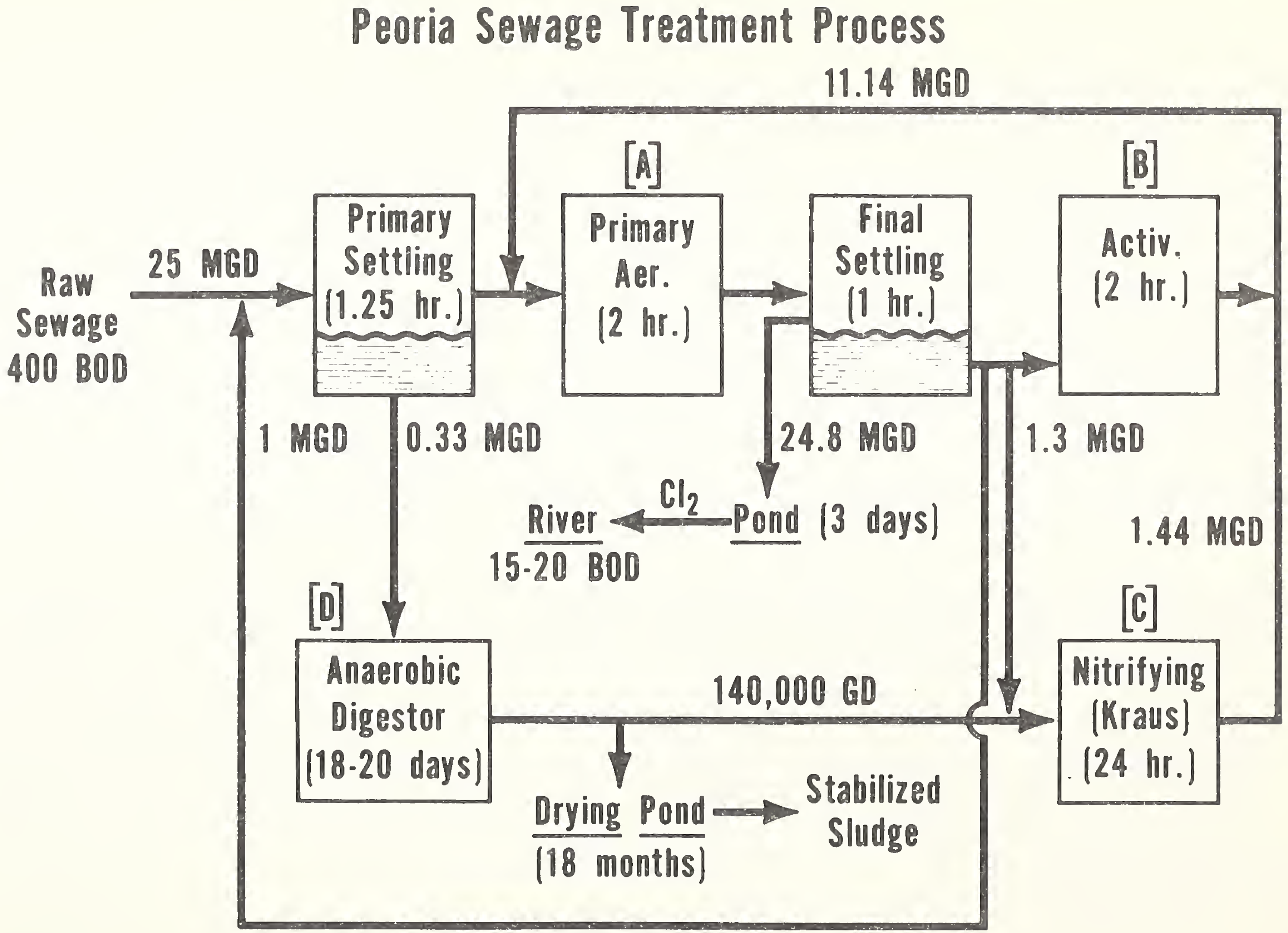

Figure 1. Flow diagram of Peoria Plant.

product obtained from activated sludge in 1.5 percent yield is different. It has a lower melting point, has somewhat different solubility characteristics, and contains both β-hydroxybutyric and β-hydroxyvaleric acids in the form of a copolymer. A film is formed by evaporation of a chloroform solution of the polymer.

We have also obtained evidence for the production of the polyester by some of our sewage isolates. Other isolates produce polysaccharides which have not yet been investigated.

In summation, our work at the Northern Marketing and Nutrition Research Division is directed toward utilization of activated sludge and feedlot waste by various approaches. If successful, quantities of usable products could become available from the large amounts of sludge and feedlot waste produced. Polysaccharides from activated sludge are biodegradable and may find use on this account. These and other products could help underwrite the cost of the treatment and elimination of agricultural and domestic wastes.

CANE SUGAR PROCESSING WASTE PROBLEMS AND CONTROL

by
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SUMMARY

As an important member of the State agricultural and industrial community, the Louisiana cane sugar industry contributes about $190 million annually to the State economy. Sugarcane is processed in 41 proprietary and cooperative sugar factories and grown in 20 of the state's south central parishes. In many of these parishes no satisfactory substitute crops have been developed.

This paper is confined to the processing of sugarcane to raw sugar in Louisiana. It does not include the operations of the six State refineries that process domestic as well as offshore raw sugar. However, many of the raw-sugar factory waste-handling problems are common to the sugar refineries.

Typically, sugarcane contains about 14 percent soluble solids (including sucrose), 14 percent fiber, and 72 percent water, in addition to extraneous field material that accompanies the cane to the factory.

The processing of sugarcane is essentially a separation or fractionation process, wherein the sugar is separated from the nonsugar material in the cane. Starting in the field, cane is mechanically harvested, burned for removal of foliage, loaded, and delivered to the factory.

At the factory, the cane is washed or laundered for the removal of field soil, and knifed, shredded, and milled for the separation of the fibrous material. In its final form, the fibrous residue is termed bagasse. By means of liming, heating, settling, and filtration, a large portion of the organic nonsugars are removed from the extracted juice.

At the evaporation station, about 75 percent of the water in the juice is removed. Final fractionation of the sugar from nonsugars is effected by crystallization, in which the final products are raw sugar (about 97 percent sucrose) and exhausted or final molasses (about 25 percent sucrose).

Raw-sugar factory waste might be viewed from an ecological standpoint in which components entering the factory confines include the raw material, processing chemicals, water, air, and natural gas. Leaving are the final products and byproducts, airborne waste (as furnace-flue gas), solid waste (as filter cake and occasionally excess bagasse), and miscellaneous liquid-waste streams. The terms airborne, solid, and liquid waste are not exclusive, as flue gas may contain solids (fly ash) and the liquid-waste streams may also contain solids (as field soil and slurried filter cake).

In such a concept, not alone the soluble and insoluble solids content of the liquid and solid wastes leaving the factory confines would be considered, but additionally the thermal content of the flue gas and the thermal and the biological oxygen demand (BOD) content of the liquid waste streams.

The raw-sugar industry is unique in the high energy requirements for power (with subsequent furnace-flue gas emission) and for evaporation (with attendant condenser or cooling-water demand). Equally of interest is the fact that the fiber in the cane provides more than enough fuel for the operation of a well-designed factory. Normally, natural gas is used only as a fuel supplement during cleanout and temporary factory stoppages. Where bagasse is sold as a

byproduct, natural gas is used for fuel and priced on the replacement value of the bagasse.

State water quality control regulations govern the BOD content of condenser water to public streams, and as a general case require the impounding of all other factory liquid wastes.

Factory wastewater quality and control studies were initiated as early as 1940, were implemented by an extensive research program in 1954 to 1956, and are being supplemented by current investigations.

Presently, the industry is investing considerable money in the redesign and modification of (1) furnaces for the control of airborne emission, (2) evaporator, condenser, and cooling facilities for condenser water quality control, (3) cane-washing facilities, and (4) segregation of factory liquid-waste streams. Equally important are continuing efforts to improve laboratory control procedures to determine wastewater quality.

INTRODUCTION

The world production of centrifugal sugar is increasing steadily and now approximates 79 million tons per year. About 11 million tons are consumed annually in the United States, of which about 6,500,000 tons are produced domestically — including cane sugar from Hawaii, Puerto Rico, and the mainland, plus in excess of 3 million tons of mainland beet sugar.

Mainland cane sugar production approximates 1,200,000 tons of which Louisiana has contributed between 540,000 to 760,000 tons annually over the past 8 years. The importance of the industry to the State is evident from the fact that cane is produced in 20 of the south central parishes, and it contributes about $190 million to the State's economy. This figure includes the income to the grower and the processor, the value added in refining, and cost of the distribution services for the final products.

Sugarcane Production and Raw Sugar Processing in Louisiana

Sugarcane averages about 14 percent soluble solids (including sucrose), 14 percent fiber, and 72 percent water. Products (with a marketable value) per ton of cane averages 170 lb. raw sugar, 63 lb. molasses, and 640 lb. bagasse.

In the field, sugarcane is propagated by means of cane-stalk cuttings, which are planted in furrows. New plant ratoons spring from the stubble of harvested cane. A normal cycle is one crop of planted cane, and two of stubble cane, followed by one fallow year in which the field may be planted in a green crop. Harvesting and the subsequent grinding commence in the early part of October and generally continue until Christmas. The cane is machine-harvested by the whole-stalk method, in which the stalks are cut at the ground level, topped, and laid in the heap rows between the planted cane. Trash is removed by burning, after which the cane is loaded in bulk and transported to the factory.

The factory processing is basically a series of separation processes, by means of which sugar is separated from the nonsugar material. Specifically the processing entails the necessary yard handling, washing or laundering to remove field soil, and prepartion by means of knives or hammer-mill devices called shredders. Through preparation, the cane rind is broken and some of the juice cells are ruptured in order to facilitate subsequent extraction.

The prepared cane is then passed through a series of heavy-duty rolls by means of which the juice is separated from the fibrous residue or bagasse. Generally water is added to the bagasse mat between mills in order to increase the extraction efficiency. The bagasse may be sent to the boilers as fuel or stored for byproduct utilization.

The extracted juice is treated or clarified by means of liming to an alkaline pH, heating, and sedimentation or settling. The settler underflow or muds are sent to rotary vacuum filters. The filter cake from this operation is discarded, while the filtrate is either returned to the juice-treating stage or mixed with the clarifier overflow.

The clarifier overflow or clarified juice (about 14 percent soluble solids) is subsequently evaporated in multiple-effect type evaporators to a 60 percent soluble solids syrup.

The syrup is crystallized (boiled) in single-effect evaporators called vacuum pans to obtain a mixture (massecuite) of sugar crystals and mother liquor or molasses. Several "boilings" of the syrup and molasses are needed to effect an economically feasible molasses exhaustion.

The mixture of crystals and mother liquor from the last or low grade boiling is sent to cylindrical storage tanks with rotating paddles and cooling coils, where the material is cooled while in motion in order to effect the deposition of additional sucrose on the surface of existing crystals.

One of the last steps in the operation is a separation of the sugar crystals from their adherent mother liquor in centrifuges. These machines consist of perforated drums or baskets which revolve at high speeds within a metal casing or bowl. The molasses passes through the sugar crystals and baskets into the casing or bowl, while the sugar is retained in the basket.

The raw sugar, containing about 97 percent sucrose, is sent to refineries for further purification. Here the products are the various grades of refined sugar and sugar products, which are retailed for specific consumer and industrial uses, as well as lower grade material which is a residue from the refining operations. The exhausted or final molasses (containing about 25 percent residual sucrose) is marketed for animal feed as well as for some alcohol production. The bagasse may remain in process, where it is used as fuel, or it may be marketed as a raw material for subsequent byproduct utilization.

General Comments on Processing as it Affects the Environment

In comparison to other agricultrual processing operations, raw sugar production is unique in the size of an investment required for the processing facilities. The cost of a modern raw sugar factory is in excess of $12 million, and current and projected economic considerations dictate factory capacities of 4,000 tons per day minimum.

Excess Bagasse and Fly-ash Emission

Energy requirements for cane preparation, milling, equipment propulsion, electrical generation, and evaporation of water are high — averaging about 1,200 lb. of high pressure steam/ton cane. (213,000 lb./hr. for a 4,000-tons-cane-per-day factory.) This energy is generated in bagasse or natural-gas-fired steam boilers. An efficiently operated factory that burns bagasse normally produces about 10 percent bagasse in excess of that required for steam generation. Factories that are located in urban areas and that burn bagasse have not alone the problem of disposing of excess bagasse, but additionally that of fly ash emission. Fly ash is fine particulate matter — generally unburned or incompletely burned bagasse. Fly ash emission may be particularly severe when the factory is being pushed by accelerated cane deliveries following a rainy spell, in anticipation of a freeze, or when handling freeze damaged cane.

Despite efforts to increase bagasse byproduct potential, only about 30 percent of the State bagasse production is being directed to byproduct channels. Among other things, this reflects problems in storing and handling the material, natural gas availability, and the cost of this source of energy.

Condenser Water

The evaporation load is considerable and reflects the water added in milling and the high water content of the cane — most of which must be evaporated in the course of processing. The heat accompanying these vapors is removed by means of condenser water. Typically, about 1,600 g.p.m. of condenser water are required per 1,000 tons cane per day (9,200,000 g.p.d. for a 4,000-ton-cane-per-day-factory). The actual volume of condenser water varies considerably, depending on the source of the water — whether it be a well, a stream, or water recycled from a spray pond or cooling tower. In the latter case, the condenser water requirements may be as much as 30 percent in excess of the figure given.

By its very nature, condenser water handling poses problems, since under the vacuum in the condensers, and as a result of contacting the hot vapors, the condenser water is low in dissolved oxygen and at temperatures between 110 to 130° F. Condenser water in a properly operated factory should have a relatively low sucrose content and subsequent BOD demand. However, defective entrainment separators, inadequate equipment capacity, or faulty operation may result in sucrose carryover and relatively high BOD levels. BOD levels varying from 30 to 350 p.p.m. were observed during the 1970 crop.

Cane Wash-water

Because of the practice of mechanical loading of cane from the field after burning, field soil accompanies the cane to the factories. During periods of rain and subsequent muddy field conditions, the volume of such material can be significant. Because of this, most factories in the State wash cane at the factory. Three factories, because of their inability to dispose of the wash-water, cannot wash cane and sustain considerable losses due to excessive equipment wear and reduced grinding rates. Some factories wash continuously, while others resort to this practice only during periods when muddy cane is received.

The volume of cane wash-water may vary from 250 to 1,000 g.p.m. per 1,000 tons cane per day (3,610,000 to 14,400,000 g.p.d. for a 4,000-ton-per-day factory). The higher rates are common with a "once-through" operation. Several factories have resorted to the expedient of a two-stage washing,. in which makeup water is applied at the final stage, while recycled wash-water is applied at the primary washing stage. This has resulted in a reduction of 1/2 to 3/4 of the once-through volume of wash-water.

Spent wash-water not alone has a high content of suspended material but a high sucrose and subsequent BOD content. Suspended solids ranging from 3070 to 5830 (once-through) to 23,690 (recycle) mg./1 were observed during the 1970 crop, equivalent to 147,000 to 285,000 lb./day. Biodegradable material, as estimated from O.C. (oxygen consumed), averaged 210 p.p.m. for the once-through operation and 1040 for a recycle system.

Filter Cake

This product from the clarification settling and subsequent filtration amounts to about 80 lb./ton of cane on an average and may be double that figure during rainy and muddy conditions. The cake contains 70 to 80 percent moisture as well as organic and inorganic nonsugars and residual sucrose. The nonsugars include those that accompany the cane from the field, such as field soil, bagacillo (fine bagasse particles), which is added to facilitate the filtration, and organic and inorganic nonsugars that are precipitated by the liming and heating operation.

From the above, it is clear that this material is high in total solids and BOD.

Yard and Floor Washings and Boiler Blowdown

Liquid waste in the yard may result from rainwater runoff. When there is considerable mangled cane in the yard, or drainage from the washed cane before or after knifing, this stream may be high in BOD.

Factory floor washings include spillage of process streams, leakage from the pumps, and residue from the usual weekend liquidation and "washout". As would be expected, this material is high in sucrose and subsequent BOD.

While boiler feed makeup is almost wholly returned steam condensate and "sweet water" condensate from the intermediate evaporator effects, chemical boiler feed water treatment is still necessary. This requires the periodic removal of the reacted chemicals as a sludge by boiler blowdown. This stream approximates 5 to 10 percent of the total boiler feed volume. This stream is high in total solids but relatively low in BOD.

Evaporator, Pan, and Heater Cleaning

Periodic cleaning of the evaporator, pan, and heating surface is necessary due to the cumulative fouling of the equipment. While cleaning is normally done during a weekly shutdown, it may be accomplished on the run, and some factories have operated up to three weeks before a cleanout shutdown is necessary.

The normal evaporator and heater cleanout schedule includes boiling with muriatic (hydrochloric) acid, followed by a caustic solution. These operations are preceded by, interspersed with, and followed by rinsing with water. Periodic cleanout of the vacuum pans is normally accomplished by boiling with caustic and rinsing.

The spent acid and rinsewater are diverted to waste while the spent caustic is returned to storage. Periodically, the caustic cleaning solution is fortified with fresh caustic, and sludge is withdrawn from the bottom of the solution-storage vessel and discharged to waste.

Excess Condensate

A properly operated factory produces more condensate than is required for boiler feed and plant-process water. In the usual system, the exhaust-steam condensate is supplemented by "sweet water", which is a condensate from the intermediate evaporators in the multiple-effect evaporator system.

Under normal conditions, sweet water is virtually pure water with little dissolved solids and essentially no BOD. When periodic evaporator entrainment occurs, however, this material exhibits a high sucrose and BOD content and must be diverted to waste.

Control and Disposition of Factory Waste

In common with other State industries, the raw-sugar factories must conform to the control and regulations of the Louisiana Stream Control Commission and the Louisiana Air Control Commission. The State control reflects State, as well as Federal, standards set by such agencies as the Federal Water Pollution Control Administration (FWPCA) and the Air Pollution Control Office.

Additionally, the Corps of Engineers is considering standards for waste streams that are discharged to navigable waterways.

Cane Washwater

Normally, cane washwater is impounded and subsequently discharged to public streams after settling and biostabilization. As currently practiced, this expedient requires a large lagooning area to impound the total factory discharge during the course of the crop.

The practice of recycling washwater, which was cited previously, can significantly reduce the impounding or lagooning area. Up to 75 percent recycle has been effectively utilized, with a corresponding reduction in impounding area requirements. While a significant decrease in the volume of washwater is thus effected, total solids, settleable solids, and BOD per unit of waste volume are correspondingly increased.

Research work in the sugar beet and sugarcane areas has been directed toward means of rapid biostabilization by forced aeration. Ideally, such a system would permit closing the cane washwater loop, so that little or no wastewater was discharged from the factory limits during the course of the crop.

Condenser-cooling Water

Condenser water meeting specified BOD standards may be discharged to public streams. This material poses a particular problem with regards to its thermal content, dissolved oxygen depreciation, and possible BOD contamination.

Where the receiving stream has adequate assimilative capacity, condenser-water temperature and dissolved-oxygen depreciation pose no problem. However, where the assimilative capacity of the receiving stream is limited due to low flow rates, spray ponds may be necessary. This expedient results in partly or wholly closing the condenser-water loop. For a completely closed system, rather extensive spray facilities are necessary. Lacking adequate facilities, a high condenser injection-water temperature can considerably increase the required volume of condenser water and the size of the condenser system.

With properly designed equipment, adequate entrainment separators, and an effective laboratory-control system, the BOD content of the condenser water can be minimized. During the past year, a comprehensive factory-control program, supplemented by research work at the Audubon Sugar Factory, has pointed up a wide variation in the BOD content of condenser water from factories in the State. As a result of these investigations, many factories are redesigning the evaporator station, the associated entrainment separator and the condenser-water system.

Sucrose losses in condenser water can represent not alone a pollution problem but additionally a significant loss in recoverable sugar. Control in this area is thus a matter, not alone of pollution, but additionally of economics.

Filter Cake

Filter cake may be disposed of by (1) trucking to the field for dressing or sanitary landfill or (2) slurrying the material with water and pumping to an impounding basin.

Disposal as field dressing or landfill is practiced by very few factories, because of the volume of material that must be handled and resulting odor problems where the material is disposed of in proximity to residential areas.

Where impounding is practiced, the mud slurry receiving basin is usually prepared for reuse by draining prior to the following crop and bull dozing the partially dried material to the side of the lagoon.

Miscellaneous Impounded Streams

The following additional streams are impounded: Yard and factory washings; boiler blowdown; heat-exchange equipment acid, caustic, and rinse solutions; and excess steam condensate.

As with condenser water, sucrose losses due to cleaning, spillage, and leaking pump glands become a matter of economics. It is notable that the industry has become increasingly aware of this and that major steps are being taken to minimize the volume of such material.

Fly Ash

With regard to fly ash, many Louisiana factories are located sufficiently close to residential areas to require fly ash arrestors on the furnaces. With properly designed and operated arrestors, this source of air pollution can be minimized. Precipitated fly ash may be trucked off the factory site as land fill — or it may be slurried with the filter cake to an impounding area.

Excess Bagasse

Because of recent regulations regarding the open burning of excess bagasse, several factories have expanded their furnace capacities such that the furnaces are both steam generators and excess-bagasse incinerators. This may be a necessary but very expensive expedient. Additional steps to improve furnace bagasse burning efficiency have included air preheaters. Several factories are investigating the possibility of acquiring incinerators for the sole purpose of burning the excess bagasse. Another expedient has been to design the bagasse handling facilities to return unburned bagasse back to the furnace during cleanout.

Biochemical Waste Reactions

Since sucrose is the primary liquid-waste contaminant, a few comments might be in order on the mechanism of sucrose stabilization. This is primarily a biochemical reaction and may be aerobic or anaerobic.

Aerobic Oxidation

In its simplest form, aerobic oxidation may be expressed by the following chemical reaction:

$$C_{12}H_{22}O_{11} + H_2O + 12O_2 \xrightarrow{1} 12CO_2 + 12H_2O + \text{Heat}$$

	sucrose	water	oxygen	carbon dioxide	water
MW	342		384		
lb.	1		1.125		

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[1] Reaction conditions: Micro-organism, nutrients, temperature.

The above chemical shorthand indicates that 1.0 lb. of sucrose (molecular weight 342) reacts with 1.125 lb. of oxygen (384 molecular weight) in the presence of the proper microorganisms, sufficient nutrients as nitrogen, proper temperature conditions, and, obviously, adequate oxygen. Under these circumstances, the reaction proceeds to complete stabilization, with the final products of carbon dioxide, water, and the evolution of heat.

Anaerobic Oxidation

Lacking available dissolved oxygen in the receiving stream, the reaction may still proceed, but some of the oxygen is taken from chemicals in the stream, such as sulfates or nitrates. In the case of sulfates, the reaction might be expressed in the following form:

$$\underset{\text{sulfate ion}}{SO_4^{--}} + \underset{\text{carbon ions}}{2C^{----}} + \underset{\text{hydrogen ions}}{2H^+} \longrightarrow \underset{\text{hydrogen sulfide}}{H_2S} + \underset{\text{carbon dioxide}}{2CO_2}$$

The above half-reaction (ions are used in part of the reaction) shows that carbon and hydrogen ions have taken their oxygen from the sulfate ions. One of the products is hydrogen sulfide with its offensive rotten egg odor. Other nuisance products may include methane, ammonia, organic acids, etc. Such anaerobic reactions must be followed ultimately by aerobic conditions to complete the stabilization.

POULTRY PROCESSING WASTES

by
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The Richard B. Russell Agricultural Research Center is almost 2 years old, so this report will focus on poultry processing waste problems and the research we are getting under way to help overcome these problems. Because of our tender age, we still do not have a great deal to report in terms of finished research, but we feel that our progress is exciting.

First, for the benefit of those who have not visited Russell Research Center, let me take a few minutes to give you a thumbnail history and describe our facilities.

We are still deeply involved in planning and implementing research programs at the Center, responsive to the changing needs of agriculture in the Southeast. As early as 1962, the late Senator Richard Russell recognized the need for a new laboratory in the Southeast to provide research guidance and technology to the anticipated influx of agri-based industry resulting from the Southeast's diversifying agriculture.

In recognition of his vision and leadership, Secretary of Agriculture Clifford M. Hardin named this Laboratory in his honor. At its dedication on May 9, 1970, President Richard M. Nixon sent a telegram that stated:

> "The Richard B. Russell Agricultural Research Center bears an illustrious name — one which stands for much that has brought pride and honor to the State of Georgia and to the Nation. I know that the results achieved at this Center will improve the quality of living for people of the Southeast, and indeed throughout the world during the years ahead. It is fitting these benefits should continue to come to use in the name of an outstanding and dedicated public servant, Richard B. Russell."

When completely staffed, Russell Research Center (RRC) will employ about 500 people, of which 150 will be senior scientists — that is, people at the Ph.D. level. We will have the widest range of scientific disciplines of any research facility in the U.S. Department of Agriculture. A strong Federal-State cooperative effort will exist for solving agricultural problems of the region. Scientists of State agricultural experiment stations, other State and Federal organizations, other divisions of ARS, and RRC will work together toward the solution of problems.

Like all functioning biological systems, a poultry processing plant uses water for transportation, dispersion, and temperature regulation. The product is at times water-flumed or transported in water-filled tanks. Waste products and nonedible liquid products are most often water-flumed. Water is used for washing and cleaning the product and for dispersing wastes. Water, under pressure and possibly heated, is used for all nonproduct cleaning operations.

Many times water is used in exchanging heat — scalding before removal of feather, for ice-making, for chilling, and possibly for ice for product shipping. During all these processes, this water has been in intimate contact with the edible product or with wastes, and as it completes its plant assignment, it leaves heavily laden with what we loosely call wastes.

Every phase of the research program on poultry under way at the Russell Research Center has been influenced by concern for environmental quality. This is true because each process either influences the environment in some way or is changed by it. For instance, a food item produced in one area of a plant can be contaminated by airborne microorganisms for the live bird receiving operation. The greatest emphasis, however, involves programs concerned with the plant effluents and inedible product disposal.

Research into developing improved systems for recovery and utilization of inedible wastes from poultry-processing plants is under way in the Research Center's Animal Products Laboratory, Arthur Mercuri, Chief; specifically in the Poultry Processing Investigations under Rex E. Childs, Investigations Leader. Douglas Hamm, Project Leader, through the cooperation of the Southeastern Poultry and Egg Association, obtained information regarding water utilization and waste disposal from 17 poultry-processing plants in the Southeast. Considerable variation existed among plants in volumes of water used for various poultry-processing operations, as well as in methods of waste disposal.

Water use ranges from about 5 gallons per bird to a high of about 20 gallons per bird. Dr. Hamm found that only a few plants had adequate waste-collection and -handling systems for removing solids and grease from their effluents.

Characterization of these effluents from various poultry operations has also been initiated under Rex Child's leadership, with emphasis on determining volume and nature of recoverable materials that can be converted into useful byproducts. Work to develop more efficient utilization of water during processing and improved slaughtering and defeathering techniques by Research Center engineers is being coordinated with the project on waste utilization. The work thus far has included the construction and testing of a final bird washer and a settling or separation tank for experiments in removing wastes from poultry chillwater and recycling it.

These studies are the first steps in establishing design criteria for more effective uses of water in processes. The engineering phases of the work are closely coordinated with the microbial investigations to assure product quality maintenance. This microbiological work is under the able leadership of Dr. Huda Lillard.

Work has also been initiated by Douglas Hamm, in cooperation with Northern Marketing and Nutrition Research Division on the utilization of chicken blood, a large contributor to poultry-processing wastes, as a constituent of a plywood glue. Preliminary results indicated that freeze-dried chicken blood is an adequate substitute for commercial spray-dried beef-pork blood as a constituent of a protein glue for interior plywood. Since blood from the slaughter operation is usually the prime source of biological oxygen demand (BOD) loading of plant effluents, a commercial-size blood-collection system has been designed and installed in a processing plant for testing. The primary purpose of these tests is to develop specifications for a completely automated blood collection system, which will essentially eliminate blood drainage into the plant effluent and greatly decreases labor requirements for cleaning up messy blood tunnels. Such a collection system will also be essential and hopefully compatible with new processes that might be developed at the Research Center for chick blood.

The rendering of byproducts and wastes from poultry slaughter operations serves a vital economic function to the poultry processor, where revenue derived from this operation may often mean the difference between profit and loss. The rendering industry also significantly contributes to the good of all by the conversion of nonedible processing residues into useful byproducts, thus minimizing the problems associated with disposal of such materials. Water and air pollution from these rendering plants, however, cannot always be economically controlled to the degree presently being justifiably demanded by local, State, and Federal authorities and by affected civic groups. The problems of malodorous vapors in the atmosphere and large BOD loads in waters, which often result from rendering operations, need to be solved. If they are not, many rendering plants may be forced to shut down or relocate at considerable expense. Such actions would pose a serious economic threat to the entire poultry industry.

Our research program must be directed, therefore, to provide assistance to the rendering industry, as well as to provide alternatives for processors in the event that centrally located rendering plants become unavailable or uneconomical. Reliable and economic sources for byproduct rendering, then, might be through a continuous process for the conventional type, or the solution might lie in completely new processes on the plant site with a new product from each type of inedible material. As resources become available, more and more of the nonedible products will be studied, with particular emphasis on new product development, as well as abatement of pollution.

Future research on rendering problems will include:

(1) Evaluation of each phase of the poultry rendering operation to ascertain the most significant sources of offensive odors escaping into the atmosphere, and of large BOD loads being discharged into streams, rivers, or local sewage facilities; and

(2) Development of chemical, physical, or engineering or all three techniques that will eliminate or substantially reduce the degree of air and water pollution resulting from rendering operations. Investigations will be carried out on methods of retarding bacterial decomposition of poultry plant residues during collection, transporting, and holding of such materials prior to rendering; on improved plant designs; and on treatment of exhaust vapors and of liquid and solid wastes emanating from poultry rendering plants.

BY-PRODUCTS, PROCESSING WASTES, AND ANTIPOLLUTION RESEARCH AT EMN

by
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PAST RESEARCH

Investigations on agricultural wastes and their utilization at the Eastern Regional Research Laboratory go back to the 1940's and 1950's. One of the earliest studies concerned dehydration of the leafy portions of vegetables, made available at processing plants, to produce meals that were evaluated for poultry feeds and as a source for extracting carotene. Methods were developed for dewatering and drying cull potatoes and pulp from potato starch factories to produce feeds; these methods are presently in commercial use. Techniques were worked out and later commercialized for recovering and drying the total waste solids from tomato juice processing. The extended aeration modification of the activated sludge method for reducing BOD was developed for treating milk wastes; extended aeration was adopted widely by dairies and has been extensively used for treatment of other wastes. A method for propagation of yeast on whey was developed and commercialized to permit great reduction of BOD while producing a high-protein product for food and feed uses. Potato starch factory effluents were researched in a preliminary manner to explore ways or reducing BOD and at the same time recover usable byproducts. The first in a planned series of contract studies on treatment of fruit- and vegetable-processing wastes was completed at Manhattan College. Research on processing wastes was eliminated, however, near the end of the 1950's because of lack of popular support for the subject at that time and the existence of pressing problems in commodity utilization.

PRESENT RESEARCH

Renewed, and indeed increased, emphasis on wastes research came about in recent years. This stems from greater national awareness of problems in environmental deterioration. The Eastern Marketing & Nutrition Research Division (EMN) responded by adopting research programs on whey utilization, biodegradable detergents, wastes from potato processing, dewaxing-lye peeling of fruits and vegetables, reduction of waste loads in hide processing and tanning, and meat-processing pollution.

Whey utilization. — In food processing, dairy wastes contribute the highest pollution loading. Twenty-one to 22 billion pounds of liquid whey is produced annually as a byproduct of cheese manufacture. Only about one-third of this is presently used. Whey now being wasted must be concentrated and dried or separated into protein-rich and lactose-rich fractions to extend the uses. Seven billion pounds of whey is utilized annually. Most of the recovered whey is concentrated and dried by roller drier or spray drier. Whey is also the source of lactose manufacture, now totaling over 100 million pounds per year, and for the burgeoning whey protein concentrate manufacture.

Roller- or drum-drying of whey is carried out as follows: Concentrated liquid whey is pumped to the "nip" between two steam-heated drums revolving toward each other. Thin films of concentrate remain on each drum, the total thickness of the two equaling the clearance between the drums. Water evaporates from the films, and dried whey is scraped from the rollers by means of knives or "doctor blades." The dried product is then conveyed to the packaging equipment. Roller-dried whey is used mainly as animal feed.

Spray-drying subjects the powder to a lower temperature than drum-drying and thus gives a product that is of better quality for food use. In spray drying, the liquid concentrate is atomized into a chamber supplied with rapidly-moving hot air. The water evaporates, and the dry powder falls to the bottom of the chamber. Whey from the manufacture of Cheddar (or American) cheese and the most common cheeses other than cottage cheese can be readily dried in an ordinary spray-drier. Cottage cheese whey, however, contains an appreciable amount of lactic acid, which goes through a sirupy, sticky phase as it becomes dehydrated. The acidic cottage-cheese whey, unlike "sweet" Cheddar whey, cannot be readily dried in an ordinary spray drier.

EMN developed a foam spray drying process that successfully dehydrates cottage cheese whey. A spray-drier is modified to permit gas injection, under pressure, into the liquid concentrate before it is sprayed into the drying chamber. Nitrogen or carbon dioxide is commonly used to foam the concentrate, which dries faster than an unfoamed concentrate. Foaming of the concentrate greatly reduces the tendency for the material to stick to the walls of the drier.

Sweet- and cottage-cheese-whey powders are similar in composition, except that the latter contains more lactic acid and less lactose. Lactose content is typically about 70 percent for cottage-cheese whey and 75 percent for sweet-whey powder. Lactic-acid content exceeds 10 percent in dried cottage cheese whey but is only about one-fourth of this in sweet whey. While the portion content of whey may not be considered high, the 12 to 13 percent dry-basis figure is quite important because of the protein's nutritional quality, its functional properties, and the fact that a great total amount is potentially available.

Laboratory and pilot-plant studies in EMN have established conditions for concentrating whey (6 to 7 percent solids initially) by reverse osmosis to produce concentrates having more than 30 percent solids. In ordinary osmosis, water passes through a membrane to dilute the solution on the other side and raise its level until pressure is equalized at the membrane. The pressure at equlibrium is defined as the osmotic pressure. In reverse osmosis, external pressure is applied to the solution in excess of the osmotic pressure to force water through the membrane and increase the concentration of the solution. In order to concentrate whey, the applied pressure must exceed about 120 p.s.i. As the whey becomes increasingly more concentrated, higher pressures are needed to effect further removal of water. At 30 percent solids whey, an osmotic pressure of about 700 p.s.i. must be exceeded to bring about a further concentrating effect.

Membranes of different porosities and characteristics are available. If the objective is merely to concentrate the whey, a membrane is used that allows water to pass while restraining the dissolved substances. If the object is to fractionate the whey solids by employing the differences in molecular volume of the dissolved substances, the membrane separation is often referred to as ultrafiltration.

Experimental data for a membrane pass that concentrated whey from 7 to 20 percent total solids showed that the protein content on the dry basis was almost tripled (from 12 to 35 percent) in this concentration-fractionation operation. The lactose content was reduced from 72 to 52 percent ash content and from 10 to 6 percent dry basis, respectively.

Ultrafiltration of whey may be carried out in passages through two or more different membranes to obtain a protein-rich and lactose-rich fraction, plus a final permeate having a much lower pollution load than the original whey. Thus a first-stage passage through a "loose" membrane retains most of the protein while passing most of the lactose, lactic acid, amino acids and salts. The second-stage treatment may consist of pumping the first-stage permeate through a "tight" membrane that retains nearly all of the lactose and much of the remaining organic substances while passing much of the salts. In such a system the COD reduction is typically from around 66,000 p.p.m. in the original whey to about 800 in the permeate from the second stage.

Desalted whey, used principally in infant foods, is produced commercially by electrodialysis. In this process the anions and cations of the whey salts are removed from the protein and lactose by migration through a semipermeable membrane toward positively and negatively charged electrodes. The concentrated whey protein remains within the chamber enclosed by the membrane. Theoretically, it should be possible to effect just as complete a separation using ultrafiltration without electric fields. At present, however, whey cannot be satisfactorily desalted by membrane alone.

The highest concentration of whey protein appears to be obtainable by gel filtration. The EMN process for preparing high-protein whey fractions was developed with the help of Hartman and Swanson's observation, at the University of Wisconsin, that whey protein is precipitated by phosphates and with the techniques of Pharmacia Fine Chemicals, Inc. of Sweden on Sephadex gel filtration. Whey is acidified to pH 2.5 with HCl, the protein precipitated with sodium hexametaphosphate, the separated protein then neutralized to pH 6.8 with sodium hydroxide, and the mixture finally passed through a Sephadex (G25 coarse) gel column to recover a 4 percent protein solution. The salts tend to be trapped in the interstices of the Sephadex particles, while the protein preferentially passes between the gel particles and on through the filter column. The solution passing through the column is concentrated to 25 percent solids and dried to yield a powder containing about 80 percent protein. The composition of a typical sample of EUPRO-80, as our high-protein concentrate has been named, is about: protein (N x 6.38) 78.7; ash 13.7; lactose 2.9; moisture 1.9.

Contract research, supported by the Eastern Division, is now in progress in which the laboratory findings are being evaluated, using commercial-scale equipment and methods. Whey is being concentrated by reverse osmosis; the whey concentrate is being fractionated, and the protein and lactose fractions dried; the most promising whey-protein fractions will be tested in new applications in dairy foods.

Sweet whey is finding widespread applications in foods. As a result of early research in U.S.D.A. and industrial research and development, sweet whey is well established for uses in: baked goods; dry baking mixes; ice cream and sherbet; confections, icings, and frostings; processed cheese. Large-tonnage uses for cottage cheese whey are more difficult to develop because of the lactic-acid content. Research in our Division has shown, that uses can be developed for cottage cheese whey, some of which capitalize on its natural acidity, e.g.: additive in rye bread, in popsicles, in pie-filling mixes, in sherbets, in dips for snacks, and in beverages.

Whey has potential utilization in two new types of foods recently developed at EMN. In one, liquid whey is mixed with soybean flour, pasteurized, homogenized, condensed, and then spray dried to give a nutritious base for a soup or beverage. Concentrated whey spread is another possibility; whey is mixed with butter-oil or cream, pasteurized, homogenized, and then concentrated to 37.5 percent butter-fat, 37.5 percent whey solids, and 25 percent water.

In short, whey-utilization research has developed many important outlets, but the vast quantities of whey that must be kept out of the streams in the future present a formidable challenge to find new and extended uses.

Fat-based detergents. — Ecologists emphasized the need to improve the biodegradability of detergents, because the petroleum-based surfactants were found to persist long after discharge to waste. Some of these detergents not only resist breakdown but even interfere with sludge digestion in sewage systems. A number of tallow-based surfactants have been synthesized, evaluated for biodegradability, and tested for the following: detergency in hard and soft water, ability to disperse lime soaps, foaming power, stability against hydrolysis, and other properties required of a detergent. Types of compounds studied include, among others, the anionics: alpha-sulfo fatty acid esters; fatty alcohol sulfate salts; ether alcohol sulfates; sulfated alkanolamides. Tallow alcohol sulfate and alpha-sulfo fatty acid esters are the two types having the more industrial significance to date. These fat-based detergents are superior to petroleum-derived surfactants in completeness and speed of biodegradation in river and surface waters. In an activated-sludge system simulating a sewage plant, the fat-based surfactants are far superior to the so-called biodegradable linear alkyl-benzenesulfonates in ease of breakdown. The relative ease of biodegradation of fat-based detergents is particularly important under anaerobic conditions such as prevail in septic tanks.

Potato, vegetable and fruit wastes. — Processing fresh potatoes gives rise to the following BOD in pounds per ton of raw material employed: for chips, 28: for frozen products, 22; for dehydrated products, 71; and for starch, 59. The population equivalent of the daily waste discharge from an ordinary-size starch plant (30 tons of starch) is 78,000. The EMN investigations on BOD reduction by recovery of byproducts have emphasized starch production, but the findings should also be applicable to forms of food processing. Optimum methods have been found for coagulating the protein and removing the precipitate, for concentrating the wastewater by reverse osmosis, and for isolating the potassium salts, free amino acids, and organic acids by ion exchange. The following products, expressed in pounds, are recoverable from the processing water of a plant grinding 250 tons of potatoes and producing 30 tons of starch per day: crude protein, 2,850; amino acids, 3,900; potassium sulfate, 4,000; and organic acids, (mainly citric and malic), 3,000. The total BOD of the processing water is reduced from 10,100 pounds to 2,100 pounds by removal of these constituents. If economics should prevent recovery of the constitutents in separate fractions, then evaporation of the processing water to a concentrate containing all of the solubles (except coagulable protein) appears feasible.

A vapor-phase (hot isopropanol) dewaxing and lye-peeling process under development for apples and other fruits has been adapted to peeling of mechanically-harvested tomatoes by a California packer. In the first season of use, peeling loss (waste) was reduced by 76 percent and lye use (requiring eventual disposal) was reduced by over 67 percent.

Animal-product processing. — EMN research on waste treatment and byproduct utilization connected with processing of animal products is in an early stage. Processes are to be developed for recovery of protein and fat from hair fleshings and trimmings made available in hide-processing and tanning operations will be sought to reduce the amounts of total solids, BOD, and water volume in the effluent to minimum values.

In the area of meat products, EMN meat-flavor investigations have included studies leading toward establishment of successful "liquid-smoke" compositions. Health authorities in some municipalities are considering banning the wood-smoking of processed meats because of air pollution. An alternative will be to dip the processed meats in liquid smoke compositions.

In this brief review, we have considered past accomplishments in the Eastern Division in environmental-improvement research and have high-lighted current research in this area. The track record is good, and we feel confident that future investigations will contribute toward solving pressing problems.

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